Mechanical Engineering

The Journal of the American Society
of Mechanical Engineers

Index to Volume 45

January to December
1923

Published by
The American Society of Mechanical Engineers
29 West Thirty-ninth Street, New York

Index to Mechanical Engineering

Volume 45, January to December, 1923

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Mechanical Engineering

The Monthly Journal Published by

The American Society of Mechanical Engineers

Publication Office, 207 Church Street, Easton, Pa. Editorial and Advertising Department at the Headquarters of the Society, 29 West Thirty-ninth Street, New York

Volume 45 | January 1923 | Number 1

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DEPARTMENTAL

ADVERTISING

Price 50 Cents a Copy, $4.00 a year: to Members and Affiliates, 40 cents a Copy, $3.00 a Year. Postage to Canada, 75 Cents Additional; to Foreign Countries, $1.50 Additional. Changes of address should be sent to the Society Headquarters.

Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879.
Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921.

Contributors and Contributions

National Leadership

That universal well-being, depending primarily upon the industrial background, may be attained under the leadership of the engineer, was the sentiment of the presidential address of Dexter S. Kimball at the Annual Meeting of the A.S.M.E.

Since his graduation from Leland Stanford, Jr. University in 1896, with the exception of a few years spent with various engineering firms, Dean Kimball has been a member of the Cornell faculty. Until 1915 he was professor of machine design and construction, and since that time he has occupied the chair of industrial engineering. He became dean of the College of Engineering in 1920.

He is co-author with John H. Barr of Elements of Machine Design, and author of Industrial Education, Principles of Industrial Organization, Elements of Cost Finding, and Plant Management, as well as of many contributions to the technical press.

Engineering and Economics

At a joint meeting of the American Economic Association and the A.S.M.E. during the Annual Meeting two papers on engineering and economics were presented. Wesley C. Mitchell who spoke on Making Goods and Making Money, is director of research at the National Bureau of Economic Research and professor of economics at Columbia University.

Dr. Mitchell was graduated from the University of Chicago in 1896 and studied at the Universities of Halle and Vienna in 1897 and 1898. He was instructor in economics at the University of Chicago for two years and in 1902 went to the University of California as professor of political economy. He joined the faculty of Columbia University in 1913.

E. M. Herr, who is president of the Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., clearly defined the manager's responsibilities in relation to the human problem in industry. Mr. Herr is a graduate of the Sheffield Scientific School, and has received degrees of D.Sc. from Franklin and Marshall College and A.M. from Yale University. He is a member of the corporation of the latter institution. Previous to his present position, which he assumed in 1911, Mr. Herr was connected in various capacities with several railway lines in the northwestern United States, with the Grant Locomotive Works in Chicago, and with the Westinghouse Air Brake Co.

Symposium on Stokers

Three papers presented at a joint meeting of the Stoker Manufacturers' Association and the A.S.M.E. during the Annual Meeting are abstracted in this issue. The authors of these articles are men of long experience in stoker work. Thomas A. Marsh, an Englishman by birth, is a graduate of the University of Illinois and since 1906 has been connected with the Green Engineering Co. at East Chicago, Ind.

George I. Bouton, for seven years chief engineer for the Murphy Iron Works, Detroit, Mich., is a graduate of Washington University. He spent seven years as engineer for Bryan & Humphrey in St. Louis, nine with the Heine Safety Boiler Co., and four in consulting mechanical engineering in New York.

Howard F. Lawrence has devoted the most of his time since his graduation from Stevens Institute to the development, operation, and general design of underfeed stokers, with particular reference to the Taylor stoker.

Tests of a Type "W" Stirling Boiler

Using information obtained from extensive tests conducted during 1921 on a large Type "W" Stirling boiler at the Connors Creek power house of The Detroit Edison Co., seventeen of these large boilers have been rebaffled with a resulting improvement in boiler-plant efficiency and an increase in the degree of superheat of the steam. These tests were described in a paper presented at the A.S.M.E. Annual Meeting and included in this issue. Its author, Paul W. Thompson, has been connected with the Detroit Edison Co. since October, 1913, as technical director of the operation of generating plants. Mr. Thompson is a graduate of Cornell where he taught heat-power engineering for two years.

Power Required for Cutting Metal

Fred A. Parsons, chief engineer of the Kempsmith Milling Machine Co., Milwaukee, Wis., through the Machine Shop Division of the A.S.M.E., contributed to the Annual Meeting a paper giving the results of an investigation to determine the fundamental laws governing milling, turning, planing, and drilling operations on the various metals and alloys used in machine construction. This paper contains formulas and tables by means of which the power required to machine metal in any given case may be calculated.

Mr. Parsons has been connected with the Kempsmith Milling Machine Co. since 1911, with the exception of a few months when he was machine designer for the Cincinnati Milling Machine Co. His early experience was obtained in various shops in Kalamazoo and in the metal plant of the Baker-Vawter Co. at Benton Harbor, Mich.

Testing Involute Spur Gears

The Machine Shop Division of the Society also contributed to the Annual Meeting a paper by Mansfield Estabrook reviewing some of the more commonly used methods of testing or inspecting spur gears. Mr. Estabrook was graduated from Harvard in 1899 with a B.A. degree and from the Massachusetts Institute of Technology in 1901 with the degree of S.B. in mechanical engineering. Since his graduation he has been with the Niles-Bement-Pond Co., except during the war, when he was a captain in the Ordnance Department, connected with the inspection of small arms.

Lumber-Cutting Waste and Production

This issue contains an article outlining the principles and application of a wage-incentive plan which has been successfully operated to reduce lumber-cutting waste and increase production. Its author, Carle M. Bigelow, chief engineer for Cooley & Marvin Co., Boston, Mass., since 1916, is a graduate of Rhode Island State College. From 1912 to 1916 he was in the employ of the Glenlyon Dye Works, Saylesville, R. I.

The Engineering Index

Attention is called to two important changes in regard to The Engineering Index: the location of the main portion at the end of the advertising section and the supplementary list of last-moment items on page 82. The reasons for these changes will be found on the editorial pages.

MECHANICAL ENGINEERING

Volume 45 January, 1923 No. 1

National Leadership[1]

By DEXTER S. KIMBALL, ITHACA, N. Y.

THE ultimate criterion by which any civilization will be judged will not be its armies or navies, its great edifices nor its wealth, but the degree of well-being—physical, mental and spiritual—that it bestows upon its people. This problem of universal well-being is most ancient and comes naturally from man's desire to enjoy the good things of life before he goes hence. The attainment of even an approximate realization of this desire was denied to all the old handicraft civilizations that preceded the present era. It does not appear to be possible to create by handicraft methods sufficient worldly comforts to support a great nation without having the larger part of the population work as menials with little or no mental development. The national ideals of all handicraft nations are, therefore, those of necessity and hold little hope of physical comfort this side of the grave.

The Problem of Universal Well-Being

But there has been born to us in these latter days a hope that this old desire may yet be realized, and this hope comes to us through the use of modern methods of production. Our civilization differs from those that have gone before, and from some that exist even today, only in one important particular. Our philosophy and our religions are built up for the most part of beliefs inherited from our forefathers, but our power to produce the necessities of life, to feed, clothe, and house the multitude, stands out as a thing apart and unlike anything that has as yet appeared on this earth so far as we have record. This power has come to us through the use of what we are pleased to call the "scientific method," by which we aim finally to replace the words "I think" with the words "I know" in all of our mundane activities. Our success in the use of this method in conquering unfriendly nature and turning her resources to our use has been most remarkable, and as it has become increasingly clear that physical, mental, and spiritual well-being depend primarily upon the industrial background, the insistence that the benefit of modern industrial methods be more widely distributed has increased in like proportion. If I read the ideals of American democracy aright, we are committed in this country to an endeavor to secure universal well-being.

Past-President Dexter S. Kimball

The benefits that have accrued to all classes of people in modern civilization are beyond question and are more apparent when comparison is made either with older forms of civilization, or even with existing handicraft nations. The general level of physical comfort and education as seen in modern nations is unquestionably higher than has ever before been attained. Nevertheless, no single class of people is satisfied with its position in the nation, and there is a deep feeling of unrest and discontent among those workers who actually produce the comforts of life. This is probably not new and undoubtedly has had its parallel in all older civilizations wherever large bodies of people dwelt closely together and where division of labor was at all a feature of industrial life. A multitude of reasons are advanced for this dissatisfaction and a multitude of remedies are offered for its mitigation, many of them having little or no bearing upon the real roots of the problem. It is obvious, however, from these suggested remedies that much if not most of these troubles have their roots in the industrial system under which we live—as might be expected, for industry is the very backbone of all existence. An examination of industrial laws preceding the present era and going back into remote antiquity indicates that modern industry has introduced few, if any, new problems. It has, however, accented and made more acute industrial problems that always arise where congregated industry and division of labor are factors in production.

Changes Wrought by Modern Methods Upon Industrial Life

Briefly, and without detail, the most important changes wrought by modern methods upon industrial life are as follows: The separation of agriculture and mechanic arts that began hundreds of years ago has been completed and widened. The agricultural worker now depends upon others for his tools of production. Within the mechanic-arts group the actual worker has been separated almost entirely from the ownership of the tools of industry. A complex system of transportation independent of either of these older fields of occupation has been developed. And, lastly, both in transportation and the mechanic arts, division of labor has been extended to a degree unheard of by our ancestors and made possible only by the use of modern tools of industry. The resulting complexity of human relations coupled with the vast increase in population has accented the time-old problem of "what is mine and what is thine?" to a point where many people despair of a solution and openly advocate a return to simpler methods and consequent simpler relations. The cry for justice, whatever that may be, is still abroad in the land, and we do not appear to have made much progress in attaining justice since the day when Plato described it as the essence of all good things.

Qualifications of the Engineer for Attacking the Problem of Effective Wealth Distribution

This charge that modern civilization is a failure or at least no improvement upon former civilizations, is, or should be, of peculiar

[1] Presidential Address at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers.

interest to the engineer, using this term in its widest sense to include all industrial workers who use the scientific method. For modern civilization is largely what he has made it, and the civilization of the future will be largely what he wishes it to be. It is too much of course to claim that the engineer, unaided, can solve these difficult problems, but it is undoubtedly true that if he will direct his energies to the problem of the distribution of wealth as earnestly as he has devoted them to its production he can make a contribution to industrial economics that will be exceedingly helpful. The engineer, and he alone, has a direct and personal knowledge of the great industrial machine that he has created. Until recently he has entrusted the operation of this machine to others who often knew little about its refined mechanism. It is high time that he took charge and operated this complicated mechanism himself.

There would seem to be little doubt but that modern productive methods on the farm and in the factory will eventually produce sufficient wealth to make universal well-being possible if our methods of distributing this wealth can be made properly effective to this end. Economists tell us that, as yet, we have not reached this point of production. It would seem, however, that even now if our energies were all bent more upon the production of necessities and less upon luxuries and pleasure-giving products, a great rise in the general level of well-being would occur. A superficial examination of every-day surroundings will convince any one of the tremendous amount of productive effort wasted now upon the things that profit us but little physically, mentally, or spiritually. To say the least, the prospect of a higher level of well-being viewed from the standpoint of necessary production is very hopeful.

Furthermore, it should be noted that the efforts of the engineer are no longer confined to the design and actual production of commodities. The principles of mass production that have so greatly reduced the cost of commodities he has now quite fully developed. The wide application of the principles of mass production has been made possible by mass financing, the work of the financier. The engineer, in turn, is now developing the principles of mass management, and his contributions to the philosophy of management are already noteworthy. I believe most business men would be surprised to know to what a large extent the methods of the engineer have invaded their chosen field, and there can be little doubt but that the near future will see the engineering type of manager a predominant figure in all industrial administration.

This adventure into a broader field has brought the engineer for the first time face to face with the greater problem of human relations in industry and the distribution of wealth. In times past he has given little or no thought to these problems, but has assumed that they lay outside of his field. This assumption is no longer true, and whether he wishes to consider these problems or not, they confront him in this new field of industrial management. He cannot avoid the issue.

It will be freely conceded that the preparation of the engineer for these new duties is far from adequate, and two of his shortcomings stand out conspicuously. The first is his lack of knowledge of the economic principles of industry and commerce. It is true, of course, that the field of abstract economics is still far from being an exact science and many of its theories are controversial. But that is no excuse for a lack of knowledge, on the part of the industrial manager, of this important and growing subject which aims to replace ignorance and empiricism with accurately reasoned results. Furthermore, every engineer is by nature an economist. The location of an industrial plant, the design of a great power house, the location of a railway are all problems in economics, and the tangible things with which economics is concerned are familiar objects to every engineer. This need in the equipment of the engineer is now fully recognized, and in a fair way to be remedied. All first-class engineering colleges now prescribe more or less economic study, and students of engineering recognize this study as a necessary part of their mental equipment.

Another important weakness in the mental processes of the engineer is his lack of knowledge of human nature and, worse still, his lack of sympathy with human problems. He is by nature a constructive individualist and usually impatient to obtain results; and, as a consequence, impatient of any obstruction, human or physical, that stands in the way of these results. And he is by nature a cave dweller given to introspection, unskilled in expressing his views verbally, and lacking usually in the companiable qualities that take strong hold upon subordinates. Of course there are many exceptions to these general criticisms, but in the main I believe they are true. This weakness, no doubt, is responsible for the failure of engineers as a class to take an interest in all civic matters and the reason why they have been, until very lately, a negligible factor in national affairs; though some of the present-day national problems are of especial interest to all men of this calling. But it would seem that this difficulty is, also, in a fair way to be overcome if one may judge by the great activity manifested lately by local and national engineering organizations in civic and national problems.

Over against these weaknesses of the engineer must be placed certain inherent qualities that strengthen his claim to industrial leadership. He is as a class essentially honest. His entire training and professional experience are such as to demand honesty of thought and purpose in all of his transactions. It is true, of course, that here also there are exceptions, but they are comparatively rare ones. Engineers as a class are honest, and if anything is needed today in management more than anything else it is this ancient virtue.

The engineer also often occupies a strategic position in industry which is of great importance in controversial matters. As the designer and planner of industrial enterprises he stands between capital and labor, and he is, not infrequently, better informed of the real difficulties at issue than are either sides of the controversy.

Furthermore, human progress must rest to a large extent upon a knowledge of the experiences of the race. This is true in all lines of human activity, and particularly true of a civilization that rests upon scientific achievement. The hope of the future lies largely in making accessible to all the great mass of accumulated experience that has come down to us. The engineer, of all men, has stood out preëminently in this respect as one who knows and uses classified knowledge to the fullest extent of his ability. The great leaders of the past had, for the most part, no conception of the importance of recorded experience. With few exceptions they took their knowledge and experience with them. The modern engineer has been the first to endeavor to reduce to written form the basic principles of industrial leadership, and his work in this field has already commanded worldwide attention.

And last, but most important, the engineer has command of the scientific method of attacking problems. With this he has practically solved the problem of production and is now rapidly rebuilding the field of administration. Is it unreasonable to suppose that he cannot make a great contribution to the problem of the distribution of wealth if he attacks this problem in the same wholehearted manner that he has applied himself to these other fields of activity? There is indeed very good reason to believe that if he makes proper preparation he will bulk large in the industrial leadership of the future.

A New Form of Industrial Leadership Needed

All thinking men who know anything about industry agree that we are sadly in need of a new form of industrial leadership, but the source of this new leadership does not seem to be clear. And it should be noted that future industrial leadership will be closely associated with political leadership, so closely are the problems of industry linked with political administration. History gives us an idea of what has occurred in the past and gives us some basis from which we can draw conclusions as to the leadership of the future. The first form of national leadership was the military type, the rule of the strong man. This extreme form of leadership still prevails in some countries, though it is hoped that it has seen its day and will soon disappear from the earth. It was natural that the military form of government should be adopted in the first factories and large industrial enterprises. And this principle has certain inherent advantages that will undoubtedly prolong its use, though the modern tendency is to modify its more extreme features. The complexities of industry and the dependence that must now be placed upon expert advisers render any form of autocratic industrial government almost impossible.

In modern democracies military rule has been succeeded by what may be termed legal government. Today our social, political,

and industrial activities are governed by a very comprehensive code of legal regulations that rest upon precedent and upon the opinions of eminent jurists sometimes affirmed and reaffirmed many times. These legal restrictions are a valuable guide since they embody the experience of the race with conditions that have occurred. The lawyer has always rendered and is still rendering a great service to humanity in collecting public opinion and codifying it for our guidance; and for this reason the lawyer has always been prominent in public affairs as an interpreter of justice as prescribed by precedent and usage. The legal method and the legal mind, however, are for the most part backward looking in their processes. They aim to correct abuses as they arise in the body politic or in industrial life, and while the legal mind is of immense value to society, it cannot be said to have developed any philosophy of industrial life that holds out hope of a solution of these problems. An excellent illustration of our modified point of view as affecting the legal government of industry is to be found in our modern compensation laws. For many years all courts have held that a workman could secure compensation for injuries only if he could prove that he had not been guilty of negligence and that his fellow-workers had not been guilty of contributory negligence. Or in other words, the burden of proof was upon him to show that the blame lay upon the employer. This legal ruling had been confirmed repeatedly and it should be noted that, in general, the worker had to have recourse to law to secure compensation. Suddenly, almost, these old laws were swept from the statute books and the modern compensation acts passed which provide that workmen and their families shall not be made to suffer because of the dangers of industry. They practically affirm that accident compensation is a proper charge upon production and should be borne by the community interested and not by the unfortunate workman and his family who, usually, are not in a financial position to assume this load. This is clearly a step toward universal well-being and indicative, I believe, of other similar changes. There is, therefore, good reason to believe that the legal type of mind is not likely to produce the much needed new industrial leadership. In fact, it is more than likely that the legal regulations of the future will not rest so much as heretofore upon ancient usage, but will be greatly modified in their viewpoint by the new industrial conditions.

There remain for consideration two other types of mind from which a new industrial leadership may come, namely, the business or financial type, and the scientific type. The business type of mind with the aid and counsel of the legal and engineering fraternities has built up modern industry as we now see it. There can be little doubt as to the ability of this type of mind to plan and direct the larger aspects of industry along existing lines. One weakness of this type of mind lies in its apparent inability to appreciate or rather to acknowledge that a new industrial day has dawned in which industry is being viewed more and more as the support of human life and not as a means of producing private, corporate, or state profits. It is rather reluctant to admit the philosophy of universal well-being as defined in the foregoing. Whether it can be made to appreciate this view is an open question.

Another weakness of this type of mind is its lack of technical knowledge of modern industry. As industry becomes more and more complex the business man is compelled to depend more and more upon the engineer for advice and knowledge. It is this very phase of modern industry that is rapidly forcing the role of industrial manager upon the engineer. The truth of these statements is shown in considering complex industrial problems like the twelve-hour shift, which is partly at least a technical problem. The best report upon this subject that has as yet appeared is the report of the Committee appointed by the Federated American Engineering Societies. It is the best because it is based upon accurate technical knowledge of the industry and not upon speculative hearsay as most of these industrial reports are. The futility of any other kind of report is well illustrated in the Muscle Shoals controversy, which could be settled quickly and accurately by a properly chosen engineering commission. If the new industrial leadership comes, therefore, from the business world, the business type of mind, I believe, will have to be greatly modified.

Dean Inge, the noted London divine, reasoning along lines similar to the foregoing, comes to the conclusion that the only hope for new industrial leadership lies with the business type of mind on the ground that the scientific type of mind is somewhat visionary or theoretical and not practical enough for the solution of this great problem. With all respect to the learned dean, I would point out that workers in the field of science are of two well-defined types, and this distinction holds true probably for all fields of human activity. In science, as in philosophy, there are minds that may be described as *minds of the first order*. These are the minds that blaze the way by seeking out new truths whether of science, philosophy, religion, or what not. At no one time in the history of the world has there been a large number of such minds as compared to the total population, and the entire list of such great prophets, poets, philosophers, and scientists is insignificant when one considers the vast number of people that have lived on this globe. It is true that this type of mind is usually visionary and impractical, for which Heaven be praised! but upon it rests all hope of future progress. The true scientist who is interested only in discovering new truths or the man whose mind is even strongly drawn in this direction is usually not capable of directing the energies of others. But the engineering type of mind (which may be described as belonging to the class of *minds of the second order*) is interested in applied science and is for the most part eminently practical when brought into contact with practical problems. It is a mind capable of high development along business and financial lines, while yet retaining in its background the powerful scientific methods of attacking problems which have made modern industry possible. And this is the great contribution that the engineer can bring to this problem of universal well-being. The one great thing we are all seeking is justice; but there is no justice where there is no knowledge, and the engineer, again using this term in its widest sense, alone possesses an accurate and intimate knowledge of industry.

No one would presume to say that the engineer alone can solve the industrial riddle, but it is clear that he can make a very great contribution to the solution. But it becomes increasingly clear that hope of a solution rests with the two groups just discussed. The National Department of Education has for some time been advocating strongly that engineering students be taught more of the fundamentals of business and that young men preparing for the field of business and commerce be instructed in some of the outstanding features of engineering. And it may be that we shall yet develop a combination of these two fields that will produce the new type of industrial leader. But whether the new leadership comes from one field or the other, or from a combination of the two, the problem of universal well-being offers a challenge and a call to duty that the engineer may not refuse. The primary conditions and responsibility for universal well-being now rest upon his shoulders, and the engineer does not like to be concerned with a half-finished "job." There is good reason to believe he will do his share of work in attaining the ultimate results desired. Already there are significant signs that he has accepted this duty. The activities of city, state, and national engineering societies in all manner of civic problems in which they are competent to express an opinion need no rehearsal here. A few years ago it was unthinkable and unbelievable that an engineer should hold a high political office. Yet today we see with great satisfaction two engineers occupying gubernatorial chairs, one of them also an inventor of note, a Past-President of this Society and possessing a mind approaching at least that of the first order. More encouraging still we see an eminent engineer chosen, for the first time, to sit in the Presidential cabinet. These are pioneer adventures in a field that hitherto has been considered the exclusive territory of the lawyer and the politician, and their experiences are being watched with great interest by all thinking engineers. They are undoubtedly the vanguard of a larger invading army.

Whatever the result, we may be assured of one thing. Unless we can in some manner change our industrial system so that we can more nearly attain universal well-being and distribute the fruits of our industry more equitably, we have no reason for believing that our civilization shall endure, and its bones will full surely strew the shores of time along with those of the great civilizations that have preceded us. But if we can solve these problems, and I believe we can, there is hope that there may arise in America a civilization fairer than any that this war-weary world has yet seen, where universal well-being shall be a reality, and not a dream, and where liberty and justice shall prevail.

Making Goods and Making Money

By Wesley C. Mitchell,[1] New York, N. Y.

Engineers and economists, according to the author, have always had a common interest in production, but they have worked on different parts of the problem and have used dissimilar methods. Recently, however, the two sets of workers have come into closer touch, because economists have begun to use quantitative methods and engineers have begun to study the whole organization of the processes of production.

Quantitative analysis of production may run in terms of money, goods, or some index of welfare. As a community we are more interested in welfare than in goods, and more interested in goods than in money. But in practical affairs the business enterprise is forced to subordinate its interest in promoting welfare and in producing goods to the necessity of making money; for if it does not make money it will cease to produce.

The system of economic organization which presents this contradiction between our deeper and our more superficial interests seems, nevertheless, to promote the production of goods and material welfare more efficiently than any other plan which men have so far devised. It is a highly flexible system, offering free scope to the inventive genius of both engineers and economists.

Among the improvements needed at present are methods of stabilizing the monetary standard, controlling the business cycle, allowing production to be organized in units large enough to attain maximum industrial efficiency while safeguarding the community against high prices, etc. Engineers are equipped to make constructive contributions toward the solution of many of these problems.

BOTH engineering and economics have been concerned with the production of wealth since their beginings. But they approached the problem from such different angles and with such different aims that at the outset they scarcely came into touch. Adam Smith and James Watt were friends at the University of Glasgow when Smith was delivering the lectures which grew into the Wealth of Nations, and when Watt was making his experiments upon Newcomen's engine. Both of these Scotchmen had a plan for increasing the efficiency of production; but one plan centered in freedom for individual initiative, and the other in a separate condenser. It was not at all apparent at the time that this economist and this mechanical engineer could contribute to each other's work.

One hundred and sixty odd years have passed since Adam Smith and James Watt started their careers in Glasgow. In this interval the industrial revolution, which was getting under headway in the 1750's, has produced a new world. Looking backward, it is now clear that this new world is a joint product of engineering and economics. Adam Smith's ideas could not have influenced the reorganization of economic policy as they did without the development of steam power. James Watt's engine could not have run its conquering career without an opportunity for individual initiative. The mathematical instrument maker of the University of Glasgow and its professor of moral philosophy have been more intimate co-workers than either dreamed.

Meanwhile engineering and economics themselves have been growing. The engineer has begun to busy himself with other things than machine designing. He sees his problem as one which takes in all phases of the process of producing goods. He is interested not merely in his mechanical equipment but also in the choice and training of the personnel, in the planning and routing of work, in the purchasing and storing of materials, in the distributing agencies which handle the product, in the methods for winning markets, even in questions of financing. Thus the engineer has begun to attack many of the problems which concern the economist.

Although it must be admitted that the progress of the economist has been less rapid, he is to be credited with trying to practice the quantitative methods characteristic of engineering. Adam Smith had "no great faith in political arithmetic." His successors, blessed with better data and knowing more mathematics, are coming to have great faith in statistics. By the development of this technique they hope gradually to establish their science upon a quantitative basis.

This expansion of the engineer's problems and this improvement in the economist's methods are bringing the two sets of workers into closer touch. Today they are conscious of their common interests, as Adam Smith and James Watt were not. They wait no longer for a later generation to perceive that they are co-workers.

Fundamentally their common problem is still what it was when Smith was lecturing and Watt experimenting. The industrial revolution which was beginning then is continuing still. Every decade since 1750 has witnessed important advances in engineering and important changes in economic problems, if not in economic solutions. The need for further progress in the technical arts of production is not one whit abated by all the marvels of electricity and automatic machinery. Nor is the need for further progress in the arts of economic organization less pressing than it was in the generations of Adam Smith, Ricardo, or John Stuart Mill. The common task is to carry forward the industrial revolution through this generation—to carry it forward in such fashion as to make it yield our race still greater benefits.

It is not likely that economists can contribute to the further perfecting of machine design, though they may render help in problems of industrial organization. On the other hand, engineers no doubt can and will contribute greatly to the solution of economic problems. To those problems they bring a special type of training, an organized method of attack, which should enable them to see many things wanting or awry in the economists' conceptions. By constructive criticism they may make the economists' contribution more efficient, and in working with economists they may learn some things of advantage to themselves.

The Three Levels of Economic Analysis

All that I have said so far is exceedingly general in character. May I go on to matters somewhat more definite? My aim is to set our common problem of production in a perspective useful alike to engineers and economists.

The process of producing goods has been viewed in three ways. Subjectively it has been treated as a process of seeking to gratify wants. Industrially it is a process of making goods. From the business viewpoint it is a process of making money.

Corresponding to these three ways of viewing one and the same process of production, there are three levels of economic analysis—the level of satisfactions, the level of goods, and the level of prices.

Economic theory long cherished the ambitious design of penetrating to the satisfactions level of analysis. It sought to explain most economic phenomena in terms of a balancing of subjective sacrifices against subjective satisfactions. In so doing it became itself subjective. So long as it followed that tack it was not possible for economists to use quantitative methods. For, despite much searching, no satisfactory units have been found in which to reckon either men's sacrifices or their satisfactions. And without units, of course, one cannot cast up totals or strike averages. At best this level of analysis yields but a dubious explanation of why men behave in certain ways—"dubious" because modern psychologists have discarded for the most part the notion that our conduct is a calculated pursuit of satisfactions.

Gradually dropping this inefficient type of speculation, economists have recently begun to develop a more objective type of work—a descriptive analysis of economic behavior, as opposed to a subjective explanation of choices. It is this shift which enables them to use quantitative methods in their theoretical inquiries. We cannot measure sacrifices and satisfactions, but we can count goods and reckon in money. Within a limited range of problems we can also go behind commodities and prices to something more fundamental and yet susceptible of measurement—not sacrifices or satisfactions, but some objective index of physiological conditions or some objective record of behavior. For example, it is possible to investigate fatigue, to grade men by intelligence tests, to study the reaction of certain occupations upon health, and so on. It is true that

[1] Director of Research, National Bureau of Economic Research, Inc.

Address at a joint session with the American Economic Association at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. All papers are subject to revision.

these efforts to carry quantitative analysis into the realm of physiology and psychology are still in the pioneering stage, but does not the success already attained suffice at least to justify faith in future progress in this direction—progress to which not only engineers and economists but also physiologists and psychologists must contribute? For convenience of reference, let us say that this type of work runs on the welfare level of analysis.

The quantitative economist, then, and the engineer who attacks economic problems are concerned with money values, with goods, or with some objective index of welfare. As between these three levels of analysis there is no question but that the welfare level is the most significant and that the money level is the least significant. Indeed, money and goods get whatever significance they possess only in so far as they represent a contribution to welfare. We rate the goods level of analysis as more significant than the money level because a bushel of wheat has a more direct and unambiguous relation to welfare than has $1.25, which may be the price of wheat on some given day.

To illustrate the practical importance of these distinctions, let us refer to the national income. We should like to reckon this income in terms of common welfare, but we cannot conceive of welfare as a magnitude. So we do the next best thing and think of the national income as an aggregate of commodities and services obtained by the nation within a year. Such an aggregate we can conceive in bushels of wheat, tons of coal, board feet of lumber, ton-miles of transportation, months of schooling, and so on. When we come to measure this magnitude, however, we are forced to express the different classes of goods in terms of money values. That is, we make our computations on the most superficial level of analysis and state the national income in billions of dollars.

We are not forced, however, to stop short with so superficial a result, for we can work back again from money to goods. Thus, when our money estimates of the income of the American people show an increase from 33 billions in 1914 to 45 billions in 1916 we can analyze this nominal gain of 37 per cent into the part due to the rise of prices and the part due to the increase of physical output between a year of severe depression and a year of great activity. By applying appropriate index numbers of prices to the various sections of the data we can get revised estimates of the national income in "dollars of constant purchasing power." These revised figures come out as 33 billions in 1914 and 40.7 billions in 1916. That is, the estimate of the two-year gain in national income is cut down from 37 to 23 per cent.[1]

For most purposes this lower estimate of the increase in the national income in which the fluctuations of prices have been cancelled as accurately as may be, strikes us as more significant than the unrevised estimate. It is easy to increase the national income to any limit by monetary inflation—easy and harmful to welfare.

Where, then, do we stand in our efforts to treat economic problems by quantitative methods? What we seek to promote is welfare, but welfare we cannot measure except in certain details where objective indexes of physiological or psychological conditions are available. So we work on the assumption that an increase in commodities and services generally brings with it an increase of welfare. It is on that assumption that we seek to promote efficiency in producing goods. But we have to measure the progress of efficiency in money values whenever we are including goods of many different kinds. While we can afterward correct our figures for changes in the price level, they still remain in money terms—a hypothetical money of constant purchasing power. And the meaning of these monetary aggregates is exceedingly difficult to interpret except when we are comparing one such aggregate with another.

The Money Economy

The various levels of analysis in economic investigation are matters of profound and practical concern to the engineer as well as to the economist.

In considering the national income it is obvious, as previously stated, that money is important because it represents goods, and that goods in turn are important because they contribute to welfare. But in the process of production as now organized these relations are reversed in large measure. Production is carried on more and more by business enterprises, and business enterprises must make money if they are to keep going. The men in charge of a business enterprise may be filled with zeal for public service, but they must make enough to pay expenses and something over or they will have to find some other way of serving the public than running a business. The men in charge of another enterprise may be engineers interested primarily in perfecting their processes and products; but they must keep their passion for technical perfection within the limits set by money profit or they will be eliminated from the ranks of business managers.

It is no disparagement of business men to say that in business they subordinate the making of goods to the making of money. They are compelled to do so by the system of which we all are parts. If they fail to get their profits they cannot go on making goods. And it is to the interest of all of us that business men should get their profits, as every period of business depression proves. For when business promises losses instead of profits, production falls off and the national income is diminished, in extreme cases perhaps by 10 per cent.

But while it is silly to blame any one for this situation, it nevertheless bristles with economic contradictions. From the national viewpoint money making is a means toward making goods; from the individual viewpoint making goods is a means toward making money. From the national viewpoint the engineer is the central figure in production; in practice he takes orders from the business man. A community is well off in proportion to its efficiency in producing a current supply of the necessities, comforts, and amenities of life; an individual is well off in proportion to his efficiency in getting a money income.

This practical subordination of our common interest in making goods to our individual interest in making money produces grave consequences. But before enumerating them, it should be emphatically stated that the money economy is doubtless the best form of economic organization for promoting the common welfare which men have yet devised. This opinion is based on the fact that the money economy has developed out of simpler forms of economic organization in all the most progressive nations of the world, and that, broadly speaking, this development has been spontaneous. No one forced our forefathers in America to give up raising their own food, making their own clothing, and cutting their own fuel. They changed from the practice of making goods for their own families to the practice of making money incomes and buying goods made by others because they liked the results of the more elaborate plan better. In medieval times the king of England traveled around the realm with his court subsisting on the produce of the royal manors. When the king began to commute the labor services of his villeins and their dues in kind into money payments, the villeins shared with the king in the advantages of a better arrangement. So almost all the elaborate machinery of the money economy has grown up by slow degrees because men thought they got more goods or better goods when they worked for money than when they produced for themselves. The villeins have been converted into wage earners, the craft guilds have given way to the merchant and the factory, the weekly markets where neighbors met to barter have been superseded by retail shops, banking has evolved from small beginnings into an ubiquitous business, the joint stock company has become the dominant form of business organization, all because on the whole these changes recommended themselves on trial to large and growing sections of the population. Of course most of these changes were accompanied by grievous hardships to many individuals, but if the new organizations had not filled demands numerous enough to make them pay they could not have broken through "the cake of custom."

It must also be set down to the credit of the money economy that it is a marvelously flexible institution. It has been developed in a dozen ways undreamed of by the medieval money lender. Its capacity for further development and adaptation to human needs has no visible limits except the limits of man's capacity for invention. With that thought in mind let us consider some ways in which the money economy serves us ill, in the hope that the engineers and economists may invent practicable devices for bettering its operations.

[1] Income in the United States. By the Staff of the Bureau of Economic Research, vol. i, pp. 64 and 72. Harcourt, Brace and Company, 1921.

Some Developments Needed in the Money Economy

To begin with an obvious point, our dollar is not a stable unit. It is subject to continuous and wide variations in purchasing power, and these variations introduce uncertainty into business plans, cause undeserved losses to some and confer undeserved gains upon others. Various plans for stabilizing the dollar have been proposed—plans which merit critical study. But this whole topic is so familiar and its challenge to our inventive power so clear that this mere mention is sufficient.

Scarcely less obvious is the problem of controlling business cycles. Economic history shows that when any nation develops the money economy to such a point that a large part of its people get their livings by making and spending money incomes, its industry becomes subject to more or less regular alternations of feverish activity, financial crisis, and industrial depression. Of late years these business cycles have been the subject of quantitative investigation, so that our knowledge of the phenomena, while still far from complete, is yet sufficient to suggest various methods of exercising control over the cycle—methods such as the systematic scheduling of business operations with reference to anticipated changes in demand, the long-range planning of construction work, the launching of new products and increase of advertising when business is dull, more circumspect granting of credit in periods of activity, the improvement and wider use of business barometers, various schemes of unemployment insurance to reduce labor turnover and sustain the purchasing power of wage earners in periods of depression, and the like. Most of these plans emphasize the policy of "prevention rather than cure;" that is, they seek to diminish the wasteful excesses of booms as the best means of diminishing the severity of crises and depressions. All these plans are in the experimental stage. Engineers by virtue of their scientific training and their intimate relations with business men are likely to take an active share in testing these schemes and perfecting the best among them.

Another problem presented by the money economy is the clash between our desire for efficient production and our fear of being exploited by very large corporations. At present the work of production is systematically planned and controlled within the limits of each independent business enterprise. But we have no systematic plan for industry as a whole. Our industrial army is like a collection of military units of different sizes each efficiently led—squads under sergeants, companies under captains, regiments under colonels, a few brigades under generals—but an army without a general staff and without a general plan of campaign. However well the separate units are disciplined and led, there is loss of efficiency through lack of coöperation among the units. Under such circumstances, every increase in the size of the independent units extends the area within which careful organization exists and lessens the area in which no planning is possible. But as the companies combine into regiments and the regiments into brigades, we are afraid that the larger units will levy upon us a tribute which exceeds the savings from heightened efficiency. How, then, can we unite the efficiency of large-scale production with safety to the consumer? To that vexed issue of economic policy the organizing genius of the engineering profession may address itself with excellent results.

Other problems might be discussed—the possibility of cutting down the overhead which business needs impose upon industry, the possibility of raising the efficiency of Government service, the elimination of all methods of making money that are detrimental to public welfare, the advantages of investment in improving the personnel of industry as compared with the advantages of investment in plant, conflicts in interest arising from the immortality of nations and the short span of individual lives, what constitutes waste and how it may be minimized, the effect of changes in the standard of living upon production, the relations between the distribution of income and production of income—all matters of concern to engineers and economists alike. But enough has already been said to illustrate the main contentions, and illustration is all that is possible in treating so wide a topic in a brief paper.

To sum up, the industrial revolution has been marked by changes in economic organization as well as by changes in engineering technique. To keep this beneficent revolution going will require further changes of both types, economic and engineering. We should not be less alert to note the imperfections of economic organization than we are to note those of mechanical methods. In one field as in the other our best hope of constructive accomplishment lies in developing scientific analysis in quantitative terms.

How to make production for profit turn out a larger supply of useful goods under conditions more conducive to welfare is a problem that gives scope for the most diverse abilities and training. It is a problem that can be broken down into manageable parts which can be attacked by quantitative methods, and the advances made by one discoverer can be made the starting point of his successor.

The Human Problem in Industry[1]

By E. M. Herr,[2] East Pittsburgh, Pa.

That the human problem in industry is not a new thing is shown by the author's review of labor conditions in the Roman Empire, England, France, and this country, from ancient to modern times. With the increase in manufacturing and decrease in agriculture, however, new elements have been brought into the problem. A much smaller percentage of the population is now working and living conditions have greatly changed. The larger scale of industry places a greater degree of responsibility upon the manager, who must win the confidence of his employees and take every step known to scientific management to secure their coöperation, both for his own benefit and for theirs. According to Mr. Herr, shop representation, fair wages, security of employment, and means for education are among the demands of workers and merit the earnest consideration of all managers.

We are perhaps inclined to consider the present industrial problems as new and peculiar to this day and age and it is somewhat surprising to find how closely the labor problems and conditions of twenty-five hundred years ago approach those of today, in spite of a total change in background.

During a thousand years of ancient times, for the most part before the Christian era, self-supporting and self-regulating organizations of workmen existed, which were remarkably similar to the trade unions of today. They were publicly acknowledged and legislative enactments made to control them, notably the Roman laws of Numa Pompilius, who succeeded Romulus as emperor, and the Greek laws of Solon (about 700 B.C.). These laws, liberal for a time when the slave element entered so largely into industry and held up even today as models by labor advocates, were to the benefit of the state as well as the workers. (The tribune Tiberius Gracchus was their able supporter.) They were weakened however, under the reigns of successive tyrants. (Caesar, under the conspiracy laws of 58 B.C., broke up all the "unions" except those which were very ancient) and finally they were lost with the Christian massacres of Diocletian in the early part of the fourth century and the subsequent feudalism of the dark and middle ages.

The immediate cause of the destruction of these far-reaching labor organizations seems to have been the coveting of their wealth and power by the rulers of the day, together with their association with the persecuted Christians. Nevertheless the Christian movement early became a helpful factor in labor conditions, although it was first opposed by the unions because of its interference with the production of idols and other supplies for pagan temples.

The records of these workers' associations (Collegia) are fragmentary, but fully authenticated as including from century to

[1] In the preparation of this paper acknowledgment is made particularly to the authors quoted in the text, to Messrs. C. Osborne Ward (The Ancient Lowly) and W. L. Chenery (Industry and Human Welfare), and to Mr. Tracy Lyon for suggestions and valuable data, as well as for information made available by the National Industrial Conference Board.

[2] President, Westinghouse Elec. & Mfg. Co. Mem. Am.Soc.M.E.

Address at a joint session with the American Economic Association at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. All papers are subject to revision.

century most of the trades and crafts of the day. Numa formally recognized nine and Constantine, a thousand years later (337 A.D.), thirty-five, of which the following list may be of some interest: Architects, brass and copper smiths, blacksmiths, carpenters, decorators, doctors, founders, fullers (cloth), furriers, glaziers, goldbeaters and gilders, goldsmiths, ivory workers, joiners, looking-glass workers, lapidaries, masons, marble cutters, plasterers of various kinds, pearl and filigree workers, potters, painters, plumbers, pavers, sculptors, silversmiths, stonecutters, statuaries, veterinaries, wagon makers, workers in mosaic.

Even professions are included, but there are evidences of the existence of many other early organizations, notably of the armorers and iron workers, shoemakers, musicians, and gladiators.

Inscriptions found in the ruins of Pompeii show that the unions furnished members to be voted for as candidates to municipal offices, and what is more remarkable, these candidates then included women. As a historian puts it, "The inscription reads like some caucus slate of a New York ward Tammany club." The eight-hour law was also an issue of the times and every seventh day was observed as a day of rest. There were many strikes, usually called historically, when they attained sufficient proportions, "servile wars." The greatest and last of these was the uprising led by the gladiator Spartacus. Practically all ended disastrously, and it is authentically stated completely extinguished all hopes of the workers for the achievement of liberty by violent means.

And so the tide of the human element in industry has ebbed and flowed through the centuries, with its vital effect upon the welfare and happiness of all civilized peoples—through the feudal and medieval times with their greater or less industrial activity, when all mechanics and traders were organized into gilds possessing important legal powers and often exercising great political influence, to the time of the so-called English (industrial) revolution in 1760, which marked the beginning of the factory system and a departure from isolated craftsmanship under oppressive landlordism.

The vicissitudes were many. Under a Statute of Labor, issued in the fourteenth century at one of the times of plague in England, it was decreed by Edward III that thereafter labor should be given no greater wage than that received before the "Black Death," about 1350.

After the French Revolution all associations of either merchants, manufacturers, or laborers were forbidden.

Early Labor Problems in this Country

To come to our own country, at the beginning of the last century there were very few factories, and those then existing had only a small number of employees. We were a rural and agricultural people—as late as 1820 less then five per cent of the American people lived in cities with a population of 8000 and over. Today we are the greatest manufacturing nation in the world and over half of our population are city dwellers.

Farmers were of many classes—the richest, masters of principalities, and the pioneers, each with but a few acres of poor clearing. Manufacturing was a home industry, carried on chiefly by farmers and their wives, children, and servants, and by wandering mechanics. The artisan was sometimes a freeman but often an indentured or "redemptioner" servant. Many of these people were imported as late as 1835, their services being bought and sold.

The hours of labor in nearly all industry were from sunrise to sunset, even in the early New England textile mills, in which women and children did most of the work. It seemed entirely right in those times that little girls of ten should work fourteen hours daily, receiving about a cent and a half an hour.

Wages were certainly not high. In Massachusetts, for instance, from 1800 to 1815 laborers received from 35 to 75 cents a day; carpenters and blacksmiths about \$1.00; millwrights, machinists, painters, coopers and foundrymen about \$1.13; a mason as much as \$1.66; tailors and shoemakers about \$6.00 a week, and women employed as domestic servants their board and 50 cents a week.

In such a world the foundations of modern industry in America were laid. From the beginning of the 19th century the factory system steadily grew with the accompanying human struggles. About 1825 occurred the first strike for a ten-hour day. "Sweat-shop" methods had then begun, but there was as yet no method of reducing the labor cost of production by the use of labor-saving machinery, outside of the textile industry.

Local trade unions sprang up more or less intermittently early in the century, principally in the shoemakers' and printers' trades, both for mutual benefit and insurance, and for the reduction of working hours and the increase of wages, but it was not until the fifties that national organizations began to take effective form. These were pretty well shattered by the depression preceding the Civil War and did not really come into being until the seventies and eighties.

With the constant growth of the factory system and the continued development of machinery, the value of all manufactured product in the United States, estimated at about \$170,000,000 in 1812, increased to more than \$60,000,000,000 in 1919, or approximately three hundred and sixty fold, while the population had increased sixteen fold.

In this comparison the consideration of relative commodity prices would reduce the output of 1919 by perhaps one-third. Prices were very high immediately succeeding the World War and accurate comparable figures of the early period are not available.

The Colonial manufacturer was the mechanic or artisan who had gathered about him a few journeymen and apprentices.

Increase in Size of Manufacturing Plants

Reference has been made to the effect on the human problem in industry of the great increase in the size of manufacturing establishments, as with this increase personal contact between employer and employed necessarily becomes more difficult.

Judging from the trend of public sentiment, it might be assumed that the factory system is practically dominated by the so-called interests or trusts, but as shown by the United States census of 1920, by far the greater number of manufacturing establishments even now are small—over eighty per cent with twenty or less hands and nearly ninety-five per cent with less than one hundred—although it is true that nearly forty per cent of the wage earners are concentrated in what might be called large establishments, and upward of seventy per cent of those having above one hundred employees. A summary of the figures is as follows:

Distribution of Establishments		Number of Wage Earners	Distribution of Wage Earners	
Number	Per cent	per Establishment	Number	Per cent
235,881	81.3	20 or less	943,586	10.3
37,795	13.0	21 to 100	1,725,683	18.9
13,661	4.7	101 to 500	2,831,456	31.2
2,768	1.0	Over 500	3,595,647	39.6
290,105	100.0		9,096,372	100.0

It may be mentioned that according to a recent authority the number of existing monopolistic "trusts"—that is, combinations controlling in the neighborhood of three-quarters of the national supply of their respective outputs—probably does not exceed one hundred, and practically all of these came into being between 1887 and 1903, nearly twenty years ago.

Under our liberal incorporation laws, perhaps too liberal in their lack of uniformity, corporate management is increasing. The proportionate number of employees and the value of the product of manufacturing corporations, as distinct from industries managed by individuals or partners, comprising nearly seventy-five per cent of the whole fifteen years ago, has increased to nearly ninety per cent.

Racial Composition of Workers

An important element in the human problem in industry of today is the racial composition of the workers. According to a report of the United States Immigration Commission on conditions before the war, the distribution of industrial workers at that time was about as follows: Native-born Americans of native father (5 per cent of these colored), 25 per cent; native-born Americans of foreign father, 17 per cent; foreign born, 58 per cent.

It is interesting to note that the first-mentioned class, or more purely American, was employed most extensively in railway transportation, the manufacture of cars and locomotives, electric supplies, firearms, knit goods, gloves, collars, shoes, cigars, tobacco, etc.

With industry dependent to such a large extent upon foreign-

born workers, the recent immigration laws threaten, for lack of "common" labor, the return to and maintenance of normal production, and it is to be hoped that these laws will be made reasonably liberal and that restrictions will be based on fitness instead of as at present without regard to the immigrant's character or qualification to become an American citizen.

Decrease in Percentage of Workers

As has been pointed out, in the early days of this country almost everyone was an industrial producer, including the housewife and children above the age of seven. It is rather surprising to find that, according to the United States Census of 1920, about forty per cent of the inhabitants of the United States support the entire population, directly or indirectly, according to the following distribution:

	Per cent	
Persons Engaged in Gainful Occupations:		
Manufacturing and mechanical industries (including building trades)	12.1	
Agriculture	10.3	
Trade and clerical	7.0	
Transportation	3.0	
Mining	1.0	
Public and professional	2.8	
Domestic and personal	3.1	39.3
Not Engaged in Gainful Occupations:		
Over ten years of age	38.9	
Under ten years of age	21.8	60.7
		100.0

Although our Government has from its inception fostered manufacturing industry, largely by tariffs and patent laws, there has been since the time of Alexander Hamilton a public feeling and belief that agriculture was the backbone of the nation and manufacturing a supplementary source of wealth. To this belief may be attributed no small part of public indifference to the ills of working conditions.

The Human Problem in Industry

Let us now turn our attention more directly to this problem in an endeavor to ascertain at least some of the directions toward which its solution trends.

There is a human problem in industry because human nature is as we find it and as it always has been. This problem, as we have seen, is as old as humanity and will in all probability continue throughout the ages to come. It has varied and will continue to vary in intensity and in character. A study of the past and present conditions, however, gives promise of a continued and steady improvement in the relations of those who make up this problem. How, then, can this improvement in industrial relations be best continued?

The principal new thing about the human problem in industry is that industry is now conducted on a large scale—larger than ever known before—and that the problem has been intensified not only by factory employment and all that goes with it, but by the greatly increased size of manufacturing establishments, by the concentration of population in cities having a large foreign element of often radical tendencies, and by the insecurity of employment, in which business cycles play a large part. Furthermore, a very large number of people are now entirely dependent upon industrial operations, as those employed in manufacturing in early days were not.

These are concrete things and all conspire to produce conditions which cause what is perhaps the greatest problem in the industrial relations of today, that is, the underlying labor unrest and distrust, born of fear and misunderstanding—fear of coercion, unemployment and sickness—and a lack of mutual confidence as between employer and employed. There is more liberty and consideration for the workers than has ever been known before, and with it has come to the workers the greater vision of what they believe should belong to them in welfare and happiness. The social responsibility of management is being emphasized as never before.

Of first importance is the responsibility of management in its broadest sense. The awakened worker of today, more sensitive than his predecessors, intelligent, critical and perhaps irritable, must be convinced of the ability of management as well as its good faith, and in extreme cases even of the necessity of its being. It is said that democracy without management reverts to despotism on the mere ground of its inefficiency, and that the fundamental error in the recent Russian failure to provide for its people was confiscation of the factories and the expulsion of the managers, with the resultant breakdown of discipline and credit, on a false theory that labor alone creates wealth, whereas management, with credit and good faith, is of the first importance in the process of production.

"Effort in itself" says King in Industry and Humanity, "is of little value; it is only effort intelligently directed that counts." The Bolshevik dictators are reported to have been compelled, as a means of existence, to resort to despotism in the name of labor in the prohibition of strikes enforced by the army, to proposals of "scientific management" at any expense, and to offers of high salaries to the old managers if they would return.

It is the duty and responsibility of the management of today to prove its "reason for being" and that the collective result of the combined efforts for managers and workers is a fine and great thing. If they can feel that this is the case, most men will toil cheerfully as subordinates.

It is management's problem to obtain the confidence of their employees, to give them every reason to believe and convince them by their experience that their treatment is fair and honest and without "bluff." Since men are naturally distrustful it takes time to establish such confidence, and they will discover very quickly if the "boss" is not square. It must be established as between man and man for the good of humanity as well as the individual that labor and management are not foes, but that their interests are in every practical sense identical.

The personnel department is now often the means of establishing, that contact with employees which is so essential, governing employment, education and welfare, as well as shop representation. Its intelligent extension still has far to go and it is regrettable that some companies have seen fit to curtail this activity in times of depression when they and their men need it most.

These relations should not be handled and directed by the personnel department alone. The active heads and real managers are the ones on whom this responsibility must rest and who must handle it with their employees, not occasionally nor spasmodically but regularly and continuously, for work of this kind requires a great deal of time and patience. This effort on their part will gain the confidence of the employees and instil a spirit of coöperation throughout the organization, and it must be exerted on those directly in charge of the daily work of production. Anything less than this is futile and doomed to failure.

Boards of directors must keep in mind this relation and work with the officers in determining policies which the managers can carry out without destroying valuable relations established only after long and patient work and almost impossible to renew.

Shop-Representation Plans

One very large organization cites good practical results of some five years' experience with a plan of joint representation of men and management "along simple, plain lines that can be lived up to." They find that if the men are free to make suggestions to the management they will not ask an outsider to do it for them, and that most questions are settled by local boards. They find that workmen are anxious to learn if given a chance, and encourage the study in factory schools of the work of other departments. This broadens their perspective and increases their interest in their own work. They want to see every worker a capitalist, with an interest in the company's stock or with a savings account. In view of the justice and importance of steady work, their personnel department has special instructions to obtain advance notice of necessary layoffs so as to provide other jobs, if possible—this for the benefit of the company as well as of the men.

It is credibly stated that at present there are in the United States more than 300,000 employees working under shop-representation plans created to give them a voice in the conduct of the shops in which they work, and that in by far the larger number of cases considerable progress has been made in establishing the most cordial relations between management and employees.

Reference has been made to fears on the part of labor, such as fears of layoff or discharge, of arbitrary exactions and reductions in wages, of unfair discipline, of ill-health, and until unnecessary fears of this sort can be removed by a better understanding and

assurance, labor is obviously incapable of devoting its best energy to production. It is consuming time in organization against ills that are feared and thereby losing its just and full reward for effort in wages and opportunity for wider employment, which would be provided by greater public confidence in the investment in industry, as well as the elimination of the enormous waste in the joint effort which such mutual fears entail.

As put by W. L. Mackenzie King:

> Consideration of how best to eliminate fears respecting the distribution of output touches the crux of the industrial problem. How is the just share of each party to industry to be determined? And how is each to be guaranteed its right to share progressively in increasing productivity, and be held also to the corresponding obligation to see losses proportionately shared?

Wages

The last-mentioned obligation is often overlooked. Nominal wages have increased enormously; according to the United States Bureau of Labor Statistics, the average hourly rate increased seven fold from 1840 to the peak in 1920, and it is safe to assert that real wages have also augmented despite the high cost of living and the fact that in the early days of industry few workers depended entirely upon their wage but were "found" many things which must now be purchased; also the employment of young children was considered proper and the mother bore an undue part in family support, both practices which are now recognized as wrong, although not as yet adequately provided against by law.

Manufacturers naturally wish to see their employees receive a wage, with reasonable working hours, which will support them in comfort. This, of course, is only possible when economic conditions will permit, as wages are not and cannot be based on the cost of living. If this condition is to obtain, the employee must live in accordance with his income and responsibilities and exercise frugality and care in his expenditures. Unless this is done, the real interest of the employer and employee will not be conserved because wages would be lifted to the point of throttling the industry. The employer must also see to it that restrictive regulations, which weaken organization and curtail output, are not employed, either generally or for the benefit of any group or class of employees. Dr. W. I. King, in Wealth and Income of the People of the United States, states this principle very clearly as follows:

> The grim fact remains that the quantity of goods turned out absolutely limits the income of labor and that no reform will bring universal prosperity which is not based fundamentally upon increasing the national income.

Scientific Management

Scientific management—which is in fact little more than getting rid of confusion and perfecting adjustments, or in other words, good management—has entered largely in recent years into the human problem in industry. Its use may be abused, of course, but as helping to avoid undue strain on the part of the worker, under modern mechanical methods, and waste of time and materials in many directions, it should be of benefit to all concerned in industry as well as to the community. It should be a part of such management to remove the cause of any hostility to the broadest application of scientific knowledge of the conditions of maximum labor efficiency, to the gain of all parties to production. The scientific management which dealt in the earlier stage with individual output in an engineering way must now deal with men collectively and develop that scientific breadth of imagination and application which is becoming a vital necessity for the welfare of a modern civilized community.

In the introduction to the last edition of Trade Unionism and Labor Problems, Professor Commons says:

> Fifteen years ago insurance and unemployment were placed last, now they are placed first in this book.

Further on he says:

> The psychology of labor, both in good and hard times, is fundamentally the psychology of a class of people whose life is insecure, who are subject to rough methods of discipline. We cannot understand the problem of dealing with labor unless we understand that fundamental fact of insecurity of employment.

The accident-compensation law has accomplished the first little step toward giving security to the job. It has shown that the only way to establish safety and security is by making it financially profitable to do so. And so shall we make it financially profitable to business to eliminate to a large extent the wage loss due to unemployment on account of sickness, on account of changes in seasons, and on account of fluctuations in business. Labor can never accomplish this result. The only possible accomplishment of it will come when the employer arranges to cover unemployment from sickness by some adequate form of insurance, to the expense of which the employee will contribute, indemnifying the employee against loss of employment from this cause (accident is now covered by our compensation law), and to lessen unemployment on account of the fluctuation in production because of changes in seasonal demand by the proper use of stocks of finished product so as to smooth out these fluctuations and also those due to abnormal variations in business activity. The latter are much more difficult to provide against as they are irregular and often of large magnitude. When very great they cannot be entirely smoothed out but can always be lessened and are a real problem worthy of the effort of any manager.

Not only do increased security and continuity of employment greatly lessen the human problem in industry but on account of lessened labor turnover and uniformity of production they also reduce the cost of the product.

Many progressive industrial organizations have gone far beyond the requirements of the accident compensation laws and the safety of the worker, incurring large expense in providing liberally for free life insurance for their employees, advantageous savings and loan opportunities, housing, service pensions, and education. This education provides employees, at nominal or no expense, with almost every curriculum desired, from the teaching of English to foreigners to a vocational or technical course, the education of trades apprentices and the training of college men for service in the manufacturing, engineering and sales departments.

Education of Workers

There are other phases of helpful education which might well be prompted by the conditions of modern industry. One of these is in pointing out how to make repetitive work, in itself monotonous, interesting. A knowledge of the "why" of their product and the use of it and of related products of other departments has been found to materially broaden the operator's perspective. Then, too, workers can be encouraged to exercise their ingenuity in devising means to lighten and quicken their work and thereby incidentally increase their earnings. With shorter working hours there arises the question of what to do with idle time. Any one who investigates the use to which the average employee devotes his leisure undoubtedly will be convinced that such employee would be much better physically, mentally, and morally if he had less idle time, for it is generally used in loafing or in amusements which consume a material part of his earnings without corresponding benefits.

The question is often raised, "Is there not a great source of satisfaction in attainment?" Work well done and with a knowledge of progress is a source of enjoyment and with many takes the place of the recreation others find necessary to their happiness. Education of both sexes in ways in which to use leisure time profitably yet pleasantly is needed. The tendency toward shorter working hours makes the training of the young to use their leisure profitably more and more important. They should be taught thrift, for a thrifty person will not uselessly waste his leisure time.

The human problem in industry cannot but be largely affected by example. H. G. Wells, in some articles written about ten years ago on the labor unrest in England, which are unfortunately quite applicable to our conditions of today, speaks of the disturbing influence of "the obvious devotion of a large and growing proportion of the time and energy of the owning classes to pleasure and excitement" and the way in which this spectacle of amusement and adventure is being brought before the eyes and into the imagination of the working man. "We have, in fact," he says, "to pull ourselves together and make an end to all this slack extravagant living. I believe that in making labor a part of every one's life and the whole of nobody's life lies the ultimate solution of these industrial difficulties."

The human problem in industry, as has been pointed out, is very complex and can never be entirely solved. We will do a great

and valuable service to humanity if we can measurably improve the feeling of confidence of the employee in the employer and gain his hearty coöperation. To obtain this much, however, in addition to our educational work in its broadest sense, we must always and fundamentally be absolutely honest in our dealings, not only honest in our actions but also in our thoughts and intentions. Unpleasant facts necessary to be told to employees should be given them as honestly as the others and very promptly so as to give them all possible time to adjust themselves to difficult or distressing conditions.

Finally, is it not clear that at least one direction of the solution of this human problem in industry is along educational lines? First, education of ourselves, the employers, to a more general understanding of the spiritual, personal, economic, and physical relations involved; and second, education to encourage and aid in every proper way the general and vocational training of the employees in thrift, especially the younger boys and girls, but also the mature but still impressionable group of young men and women who are keen to learn how their position in the workaday world can be improved. Example in this effort to educate and train the employee is especially effective. Such educational effort should establish confidence and encourage coöperation. It should also be directed so as to develop individuality in each workman and woman. The sense of individual progress and freedom was the controlling motive with the founders of this great country. By keeping this characteristic strong in our young people we will perpetuate, strengthen, and develop the true American spirit in our land.

Let us therefore substitute the rule of reason and intelligence for force and so endeavor to restore in America the freedom of the individual, be he employer or employee,—"that freedom which enables the young man to look into the future with confidence, knowing that the only limitations to his achievements are the boundaries of his intellect and the measure of his energy."

Discussion at Engineering and Economics Session

AT THIS session of the A.S.M.E. Annual Meeting, held in the auditorium at 8 p.m. on Wednesday, December 6, under the joint auspices of the Management Division of the A.S.M.E. and the American Economic Association, two papers were presented: namely, Making Goods and Making Money, by Wesley C. Mitchell, Director of Research, National Bureau of Economic Research, Inc.; and The Human Problem in Industry, by E. M. Herr, President, Westinghouse Electric and Manufacturing Company. The texts of these papers appear on the pages immediately preceding.

President Kimball, in calling the meeting to order, said that the occasion was undoubtedly unique in the history of professional organizations. The American Society of Mechanical Engineers had long been interested in many joint activities having to do with a wide range of affairs, engineering, scientific, humanistic, but so far as he was aware, this was the first time that engineers and economists had gotten together in joint session to see what one might learn from the other.

Later, in opening the discussion, President Kimball said that Dr. Mitchell had brought forward probably the most important problem that engineers have before them today, namely, how are they to obtain this knowledge of economics to which he has referred? Colleges of engineering began some years ago in an endeavor to have all students taught the elements of economics, and the largest institutions now require a certain amount of instruction in that subject. It is not an easy thing to secure the attention of the students, however, for to them it seems a strange subject. That is natural, because we all are afraid of the things we do not understand, and just as the engineer was afraid of economics, others are afraid of engineering.

We are in need of some common basis, some common denominator of thought, and one of the first changes which has to be brought about is the simplification of the language which the engineers and economists speak. When we get to the point that we can write the elementary principles of engineering and economics so that he who runs may read, there will be some hope of a mutual understanding.

Discussion by Prof. H. R. Seager[1]

I find myself in such full agreement with both Dr. Mitchell and Mr. Herr that instead of criticising I will ask you to consider another application of the clarifying distinction Dr. Mitchell made between the money, the goods, and the welfare aspects of our economic relations. He called his paper Making Goods and Making Money. Perhaps the best title for my remarks would be Making Men and Making Goods, for I wish to direct attention to a problem which has its money aspect and its goods aspect, but which can be solved satisfactorily only by reference to its welfare aspect. It is in weighing against each other gains that can be stated in terms of goods and gains that can be stated only in terms of welfare that economists and engineers have their most difficult task. Or perhaps I should say that it is in connection with the goods plane that engineers should be able to render their greatest service to economists, and in connection with the welfare plane that economists should be able to repay some of their debt to engineers. But, as Professor Mitchell pointed out in dealing with welfare problems, we lack the exact means of measurement which we have when considering monetary or goods problems. Argument must take the place of demonstration, and in the end equally intelligent men must often agree to disagree.

Let me illustrate by reference to a practical problem that is sure to receive an increasing amount of attention during the coming year, the problem of the restrictions that should be imposed upon immigration. If this problem were to be decided as a problem merely of making goods, we should all have to agree that the present restrictions, the virtual exclusion of Chinese and Japanese immigrants and the limiting of immigrants from other countries within a year to three per cent of the number from each country who were shown to be here by the census of 1910, are obstructing the material progress of the country and should be repealed.

As a result of the war that steady stream of immigrants, averaging a million a year from 1910 to 1914, which used to recruit our industries, was largely checked. The net gain in our foreign-born population from 1910 to 1920 was thus only 3 per cent as contrasted with 31 per cent in the preceding decade, and from constituting 16 per cent of our total in 1910 they had come to constitute only 14 per cent in 1920. In 1921 wholesale misery in Europe was balanced by widespread depression and unemployment in this country. There was danger that immigrants would seek our shores again in large numbers when our industries were unable to afford employment even to our own citizens. It was to meet this situation that Congress in May, 1921, passed the per centum limit act which in May of this year was extended for another twelve months.

Our industrial situation is now quite different. In all parts of the country our industries have revived and in place of unemployment we have at present a real scarcity of many types of workers. It happens that this scarcity is most acute in the case of unskilled laborers, the very type that predominates among our European immigrants.

The arguments for letting down the bars and allowing the hundreds of thousands of laborers we could undoubtedly employ to enter are, from a business point of view, very strong. By maintaining or even advancing our standards of admission as regards physical fitness we could undoubtedly secure in large numbers just the type of sturdy and docile workers for which our industries are now clamoring. Accustomed to much lower wages than prevail in this country, these men would accept with enthusiasm current rates of pay, and the trend of wages upward which is proving embarrassing to our reviving iron and steel, copper mining, and other industries would be checked. Moreover, immigrant labor from a national point of view is always cheap labor. Other countries have borne the cost of rearing immigrants during the unproductive years of childhood, and in admitting them in early manhood we reap the full benefit of this investment without having to contribute anything to it.

There can be no question, then, that a return to our more liberal

[1] Professor of Political Economy, Columbia University.

prewar immigration policy would enable us to increase substantially our output of goods, and of this large output a goodly share over the wages we should have to pay for immigrant labor would remain as profits to employers and investors and constitute a net addition to our national wealth.

Notwithstanding these certain material advantages, economists very generally oppose a return to our former liberal immigration law and for reasons with which we are all familiar.

In this matter there is much more at stake than our national wealth. It goes to the very heart of our national welfare. Although most of us did not realize it, the admission of an average of a million immigrants a year before the war came dangerously near to wrecking our country, politically, socially, and economically. In saying this I do not intend to assert that our native Americans are demonstrably superior to the immigrants who come to our shores even from Southeastern Europe. What is certain is that they are more familiar with our institutions, more generally convinced that these should be maintained, and better trained in their operation.

When we admit an immigrant we admit not merely another pair of hands for our industries, but another potential citizen to strengthen or weaken our vital national institutions. Under the present 3 per cent restriction 357,803 immigrants may enter the country during the current year. The number who will actually come in will be substantially less because the countries of northern Europe will not send us the quotas to which they are entitled and which we should gladly welcome, while the countries of Southeastern Europe will be permitted to send us only a tithe of those who eagerly desire to come. But though the number may not exceed 250,000, or a quarter of the prewar average, economists generally feel that that will be quite as many as we can wisely undertake to assimilate in these troublous times.

The truth is that we have on our hands a highly difficult problem in trying to educate our present one hundred and eighteen million people to a better understanding of some of the elementary facts of economics and government, and cannot afford to complicate this task by admitting too many whose ideas and standards are already fixed. According to a recent writer,[1] the maximum population which the continent of the United States can support is about 200,000,000 and to maintain even this number it will be necessary to import nearly if not quite one-half of our food supply from abroad. Moreover it will take less than 200 years for us to multiply to this extent even if we make no net additions to our foreign-born population in this period. These estimates may be exaggerated, but they emphasize forcibly the truth that our population will multiply quite rapidly enough without any immigration, and that our great concern henceforth must be over the quality rather than the quantity of our people.

According to one of our leading biologists,[2] owing partly "to the great influx of foreigners of low mental capacity," but even more to the relatively larger families of our less intelligent natives, "our average intelligence has probably been declining for the past twenty-five years at least." Just what this means was brought out in startling fashion by the results of the intelligence tests applied to the 1,700,000-odd drafted men during the war. According to the same writer these tests indicated that 45,000,000, or nearly half of our population, "will never develop mental capacity beyond the stage represented by a normal twelve-year-old child, and that only thirteen and a half millions will ever show superior intelligence."

Clearly we need a respite from adding further to the number of our population of the routine manual laboring type and should concentrate all the time and attention we can spare upon means by which we can prevent the 45,000,000 at the bottom of the intelligence scale from further multiplying while we increase the thirteen and a half million of superior intelligence until they become the predominant American type. Unless we thus deliberately subordinate our goods or wealth interests to our national-welfare interests the rights to life, liberty, and the pursuit of happinesss, which we still consider our most precious national inheritance, will lose their only certain sanction, a representative government responsive to an intelligent as well as independent citizenship.

[1] R. Pearl, Proceedings National Academy of Sciences, June, 1920.

[2] E. G. Conklin, The Direction of Human Evolution, p. 104.

Discussion by Ernest F. DuBrul[1]

In the first part of his paper, Dr. Mitchell comments that engineer and economist today are conscious of their common interests and perceive that they are co-workers. This comment is of course evidence that they have not been collaborating in the past to any great extent. In his presidential address to the American Economic Association last year, Dr. Hollander brought out the costliness of this lack of contact during the war, how the neglect of economics led to misguided policies in labor adjustment, price fixing, revenue provision, and banking administration. He showed that on the one hand economists failed to mobilize as other scientists did, and on the other there was no instinctive recourse to the economist on the part of public authority, as there was to other scientists.

It is truly regrettable that instead of economics being recognized as the human, humane science that it really is, instead of it forming a valuable part of the business world's working knowledge, we find it considered, and for the most part still taught, as some form of esoteric mental gymnastics for college students. It is high time that both the economist and business man take effective steps to bring economics into its own proper place.

Dr. Mitchell has said that "engineers no doubt can and will contribute greatly to the solution of economic problems, to which they bring a special type of training which should enable them to see many things wanting or awry in the economist's conceptions. By constructive criticism they may make the economist's contribution more effective and in working with economists they may learn some things of advantage to themselves." As one working with both elements I can add a hearty "Amen" to that statement. More than that, I would appeal to both elements to give sympathetic attention to what each has to offer in the way of constructive criticism.

I do not lay all the blame for lack of collaboration on the economists; the greater part rests properly on the shoulders of the business men and the managing engineers. Measuring the great economic progress of the world, we may jump to the conclusion that economics cannot be of much value since so few of the business men who brought about this progress know anything of economic theory. But measuring the human element we find that very few people in all the world ever undertake a business enterprise, and of those few who do, a very large proportion fail, and the failure are not all small ones by any means.

It is not illogical to presume that more knowledge of economics would make far more successful business structures, just as more knowledge of other sciences and their better application has made more successful mechanical structures. We no longer leave the design of costly and important mechanisms to men who disclaim and even disdain the worth of education in physics and mathematics, because we have found the percentage of failures to be less when we had those mechanisms designed by men trained in theory as well as practice. The engineer's function is to consciously coördinate practice and theory, and to do this he must have a knowledge of both.

In puzzling out reasons for the lack of contact between business and economics, I have concluded that it is because, in sales terms, business has not been "sold on economics." To the suggestion that economic science deserved being "sold" to business, an economist of the academic type gave me the shocked response: "Why, that would commercialize the science, and destroy its cultural value in our course." To my unacademic mind economics, like engineering, is essentially commercial. I think it could be made decidedly more cultural than it is now if more teachers taught it as a science of living humans instead of as though it concerned on economic specimen preserved in academic embalming fluid. Far from shrinking at the fling of commercialism, I am for selling economics to the business world, as we have sold chemistry, physics, mathematics, geology, and other organized divisions of human knowledge.

We business men have learned that to procure consumer acceptance for our goods we must hunt out, run down, coax, stimulate, and manipulate our demand. We have learned that such acceptance depends—

1 On the sales effort made, its attractiveness and effectiveness

[1] General manager, National Machine Tool Builders' Assn.; Mem. Am. Economic Assn.; Assoc-Mem. Am.Soc.M.E.

2 On the service we give our customers to keep them sold after we have reached them
3 On the effective utility of the goods we have to sell
4 And least, perhaps, on the price we ask.

In analyzing a sale we business men have also learned the four steps through which we must lead our customer's mind to accomplish the desired transfer of our goods to him and his money to us. These are: attracting attention, arousing interest, creating desire, and inducing action.

Wherein have purveyors of economic science failed in these? As to attracting attention, many of the best of our economists seem to prefer academic retirement—and ease—to the hard work necessary to popularize the science. They may have a mistaken notion that it is unscientific or unprofessional, or undignified to make a science so popular as to promote effectively its application to every-day life. If any science ought to be and can be made popular it is economics, the one that deals with getting our living.

The opportunity of arousing interest in economics is ever present. Business men are always interested in the question, "How is business?" Their wives often talk about the domestic labor supply. Workingmen think a lot about jobs and wages; politicians and citizens think about taxes, and the gathering and spending thereof. Even professors worry at times about the cost of living and whether the latest drive for endowments will be successful enough to increase their own salaries. It would seem very noble to do everything possible to direct this general interest toward constructive rather than destructive action.

Economists have evidently not created much desire, much appetite, for economics; and Dr. Hollander gives testimony that in the great war crisis they did not induce good economic action. Perhaps it is because they have not presented their wares in an attractive, appetizing manner. Dealt out as dry, unpalatable brain fodder, economics cannot have as strong an appeal as if served in the form of a sparkling beverage to quench a human thirst for knowledge. Because it has been subjectively treated, as Dr. Mitchell has said, it seems to me that the quality of the wares has been defective. It is a fatal defect in economics to assume as true for the whole what business experience proves to be true only for a part, or to assume as true at all times things that are actually true only a part of the time.

Men of course think only as they know, and of course they write as they think. Few writers of economic texts have had business experience. They mostly have but limited knowledge of fabrication and exchange. Their personal exchange experience is limited to purchasing the most evanescent of all goods—food, clothing, shelter. So they subjectively formulate laws of supply and demand from that consumer angle, and apply that formulation to a mere abstraction, the economic man, buying and selling goods and services in a perfect economic market. But this method takes no account of the human element swayed by caprice and favoritism, and hampered by ignorance and folly. According to this theory the seller always extracts the last penny of profit from every sale. It must be the engineer's function to constructively criticize such a formulation of theory.

Take the absurd expressions, "normal price," "normal wage," "normal profit," "normal business." The "normal price" notion leads people to chasing price-fixing rainbows, meanwhile baying the word "profiteer." The "normal wage" notion leads unions to attempt to level up wages regardless of efficiency. The "normal profit" notion leads to envy of superior capacity that can make two healthy blades of grass grow where most competitors can only get one sickly sprout. The silly "normal business" notion leads men to run their business craft aground when the tide of demand goes out. That fallacy of a "normal business" has destroyed much wealth and wasted much human effort. Men have complacently considered a boom quite the normal thing, only to bewail the abnormality of the succeeding depression that their complacency brought on.

Striving for a fallacious simplicity of statement, economists have sacrificed clarity of thought in formulating so-called "economic laws." The subjective method developed a formalism that led men to believe that the so-called law of supply and demand was something external, universal, and automatic in its operation like the law of gravity, and that business simply consists of fabricating goods and making a price that takes the goods into consumption. The business world never could and never will recognize that sort of purely imaginary market.

Every business man knows that fabrication is not difficult but that sale at a profit is. It is not impossible to start a new automobile factory and make a better car at a lower cost than the "flivver," because the limit of invention is not yet in sight and Mr. Ford is still a human being, in spite of all attempts to deify him. Suppose such a factory were started, and its owner, counting on the automatic operation of the law of supply and demand, were to make a lower price than Ford's, and just wait for customers. Would he find Emerson right, that clamorous buyers would beat a path to his door, elbowing each other out of line to secure one of the new cars? Personally, I would wager that the Ford sales organization would put more "flivvers" on the road, and at a higher price.

Again the usual generalization is fatally defective when a depression comes on, when nobody wants to buy at low prices; or when a boom develops, when every one wants to buy at high prices. The usual explanation of these things is, "Well, that is abnormal; it just cannot be explained by the formula." Another important fact is that the relative elasticity or inelasticity of demand in its response to price movement is vitally different for different commodities at all times, and is different for the same commodity at different times. Economic theory has concerned itself but little with the effects of this inelasticity in different businesses.

England's leading economist, Alfred Marshall, seemed to think that only in the case of a coffin maker working for a local poor house would it be impossible to stimulate demand by lowering prices and that with this limited exception, the law as formulated by him is universally true. Yet manufacturers of industrial machinery of all kinds, whose yearly sales amount to hundreds of millions of dollars, are precisely in the same boat with this coffin maker, and unless they manage their business craft according to actual facts and not by generalized errors they are sure to lose their ventures. The whole mechanical engineering profession is largely effected by this little considered but very important characteristic of inelasticity of demand for some goods.

Making plant equipment of all sorts constitutes a very large part of total production from year to year, and each year it constitutes an increasing part. How many engineers recognize that such a business cannot be continuously operated according to the notion of a "normal," because of the nature of its demand? Demand for production machinery is entirely secondary, dependent on the demand for the product of the machine, and becomes effective in orders from three sources:

1 From wear-out
2 From expansion in the market for the machine's product
3 From improvement of the machine reducing the cost of the product.

Unlike demand for food and fuel there is little recurrent demand arising from wear-out or consumption of machinery. Well-built machines are relatively long-lived so that actual wear-out is slow, and as improvement is always proceeding there is a diminishing market each year for old types of machines. Expansion demand comes on only when the machine builder's customer is starting a new shop or is making additions to his capacity to take care of prospective increases in his own demand. This is done only well along in the prosperity stage of a business cycle, and it stops before the boom is over, as soon as the user sees his own temporary satiety point looming up. Obsolescence or improvement demand is largely an expansion demand, since it involves greater production per machine. Expansion demand comes on late in the cycle because most men lack both the money and the courage to expand their plants during depression. The consequence is that a machine industry's order curve would show relatively sharper peaks and wider valleys than consumer goods demand would show. For good reasons, until the particular cycles of the machine-using industries are controlled, buyers will mostly continue to place their orders in that fashion, and will not be tempted by the low prices made in a depression to do otherwise. The machine builder and his employees can feast only as the buyer spreads the feast.

Not knowing much of the practical effects of this inelasticity, but assuming that all demand can be made to respond in the same theoretical way to a reduction in price, Prof. John R. Commons

gravely proposes an absolutely uneconomic scheme, falsely but attractively labeled "unemployment insurance." It is not insurance at all, because it does not distribute the risk of unemployment over a considerable base or over a considerable time. It concentrates the risk on the last employer unfortunate enough to be compelled to lay off a workman at a time when jobs are scarce in his locality and industry.

Certainly conditions of demand and supply for machinery are decidedly different from those for butter. So even though this scheme which it is proposed to apply to all employers alike, might work no great hardship on a butter manufacturer, that is no good premise for a conclusion that its effects would be beneficial in the machine industry. Such superficiality is coupled with a praiseworthy desire to do a really constructive thing—to provide a reserve out of which workers can better support a business depression. But the good motive does not cure the bad logic that is being used to further this uneconomic legislation in Massachusetts and Wisconsin at this time.

Is it any wonder that business is not "sold" on that kind of economics? Can business be blamed for scoffing when such manifest fallacies are gravely put out for public consumption by an economist of some standing without much, if any, criticism from this confrerès? Unfortunately it is just such economic stuff-and-nonsense that attracts the attention of the unthinking mass and arouses their interest. It is easy to create desire for something that looks so easy to get—at some one else's expense— and to induce legislative action regardless of logic and real economics. And so the sale is made—here and in Russia. Then, when private initiative is so hampered that industry withers, the public finds—too late— that it was "sold" —in the sense the bunco man uses the term "sold."

Good economics does need selling of the right kind, to replace the spurious goods mostly current on the market. To do that sort of selling will require men of the engineer type, who are now preferred to the superficial hand-shaking type where any project of importance is under way. The engineer salesman with a professional, scientific background knows his goods and their application, and knows how to engineer the sale. I believe that when the engineer takes up economics seriously he will want to "sell" it to business, and he will keep business "sold on economics" in the proper way. As the engineer is essentially one who carries out the application of other sciences in the furtherance of human welfare, perhaps we would call this class of man an Economic Engineer.

Discussion by President-Elect Harrington

There is being carried out before us today one of the greatest experiments the world has ever known in the endeavor to level all standards of living to one common standard, to be applied to all the people. A large portion of the Russian people, however, have been disillusioned in regard to the possibility of doing that. The theoretical governments that have been set up in like fashion have all failed whether on a large scale or small scale, and their endeavor to level the standards of living and to adopt uniform production and consumption has failed.

The support given to these ideas has resulted from reasoning from the particular to the general—the endeavor to establish general laws from a theoretical consideration of individual cases. The economist must, of necessity, establish his general laws in that fashion. The result has been that in this country recently a number of pronounced errors have been perpetrated in the endeavor to apply to the nation as a whole deductions made from a few individual cases, without regard to locality or local conditions.

The organized workmen have sought vigorously to reduce all wages and all returns for labor to a common standard. And during the late unpleasantness with Germany, when our Government was concentrated in the hands of a few, and operated in a very arbitrary manner for the sake of winning the war, advantage was taken of that situation to establish by law certain uniform standards of payment, not standardizing the living, but standardizing the payment.

Out of that condition there has arisen the idea on the part of organized workmen that a standard of living could be established that should be adopted and used throughout the country. And it has further been contended that something like $2000 a year is necessary to sustain in reasonable American fashion the theoretical family of five of the workman, and various endeavors have been made to extend the view that that rate of payment is essential in probably our greatest industry, that of transportation.

It therefore has been brought about that in some portions of this country today the standard wage fixed by law or by the regulation of a commission is double in that particular industry what it is in corresponding industries in like localities. It is an absurdity to apply the same rule in those portions of the country where food and living conditions are comparatively cheap as in those portions where they are comparatively dear, for excess wages paid to any group in any community are paid at the expense of the other members of that community.

It would seem, therefore, that in studying the welfare conditions in this country we have got to consider very carefully the question of differences in locality. For example, it is very difficult to convince the southern tenant farmer, who has never received as much as $500 a year and has a poor little house to live in, that his fellow in the same community employed on a railroad is entitled to three or four times that wage. He knows that a rank injustice is being done by law.

It would be very simple if we could only reduce all of the general laws to a common formula, applicable to anybody and everybody: it would avoid thought and effort. But we must deal with the narrow, with the individual case and bring up the standards of living in some portions of our country, which are entirely too low at the present time—too low for a wise government and for the wise development of our people; while in others there must be repressed the tendency to secure more than rightfully belongs to them.

It is high time that we addressed ourselves carefully to a broad consideration of the differences in the living conditions of the people of the various parts of the United States, and the rightful compensation which they should receive. We cannot possibly afford to let living conditions go on as they are and have been going on in certain portions of the United States where they are so low that the character of the population is far below the American standard. These conditions, strange to say, do not prevail so much in our larger cities as in the poorer agricultural districts, where education is scanty, where it is difficult to train the people to think about their own condition or to reach them, where the citizenship is widely scattered and it is hard to bring them into a common condition for their own benefit, and where organization is out of the question. The city problems have had many times the study put upon them and are in course of solution, but the problems of our scattered and backward agricultural population are not receiving the consideration their importance warrants, and more attention should be given to them by economists and engineers.

Discussion by Past-President Fred J. Miller

In the development of our modern economic and industrial life we have gotten in some way too far away from the conditions that obtained in the earlier and more attractive forms of industry. The nearer we can get to a simpler ideal in the development of industry, the nearer we shall get to solving many of the difficulties that now confront us in our industrial civilization. I believe in the conditions of economic freedom with a natural leader of the shop to mass the helpers or employees, so that they can, as a group, do better work—and with more profit—than they could do working as individuals, each applying his labor to the materials of nature for the support of himself, working for himself and devoting all his efforts to his own benefit.

Our modern system develops leaders of that sort to a great extent, but at the same time we have drawn into the development of our industrial life certain restrictions around that very association that would not take place under simpler conditions, and I believe that it would be desirable to find some way of doing away with these restrictions, so that these natural associations would come about more readily. The leader, even under those conditions, would be adding to the value of the labor of every man under his direction and would thereby receive the larger reward that is due, and properly due, those capable of directing large operations, who should be liberally paid for their services. There would then be no doubt that each man working under such a leader was receiving what was his due, and that the man who did the leading was receiving what he should fairly and rightly expect.

Developments in Stoker Practice

ONE of the outstanding features of the 1922 Annual Meeting of The American Society of Mechanical Engineers was the well-attended and closely followed joint session of the Fuels Division of the Society and the Stoker Manufacturers' Association, held on Wednesday, December 6. At this session three papers were presented dealing with the various types of stokers that have been developed for the firing of boiler furnaces: namely, The Development and Use of the Modern Chain Grate, by T. A. Marsh; Overfeed Stokers of the Inclined Type, by Geo. I. Bouton; and The Design and Operation of Underfeed Stokers, by H. F. Lawrence. A Chronological History of Stoker Development to the Present Day, by A. H. Blackburn,[1] was also presented at this session. Extended extracts from the three papers dealing with stoker practice immediately follow.

The Development and Use of the Modern Chain Grate

By T. A. MARSH,[2] EAST CHICAGO, IND.

After discussing the need of progressive combustion of the several constituents in coal, and the variations in grate designs to handle different coals, the author takes up the improvement of chain-grate practice as regards air-tightness, cooling, size of combustion space, etc. He shows how a greater boiler capacity can be obtained by increasing grate size or by more intense natural or forced draft (0.50 to 0.60 in. for a combustion rate of 40 to 45 lb. per sq. ft. of grate per hour), but states that high and sudden overloads are best met by forced-draft chain grates burning 55 to 60 lb. of bituminous coal per sq. ft. per hour, with air at 2 in. pressure distributed through compartments between the runs of chain. He describes such equipment, and states that 200 per cent of rating can be reached in 8 min. from a short-banked fire, or in 52 min. from a cold grate. The paper concludes with a table of results obtained in a number of stations equipped with chain grates.

ANY STUDY of the adaptability of various stoker types and their proper functioning as fuel burners must start with an analysis of four constituents in coal, namely, moisture, volatile, fixed carbon, and ash; or roughly, water, tar, coke, and dirt. These constituents are so dissimilar that each must be differently treated in the combustion process, and specific means for burning them in proper sequence must be provided in stoker and furnace design. These facts at once determine as fundamentally correct those types of stokers embodying the principles of progressive combustion, by which is meant in practice a continuous movement of coal through the furnace and the providing of definite treatment at proper time and place for the burning of each constituent of the fuel.

Chain grates embody the principles of progressive combustion. As coal is fed into the furnace, the moisture is vaporized; then the volatiles are distilled and burned in suspension, followed by the burning of fixed carbon. Finally the ash is discharged over the rear, and the air space of the grate is automatically cleaned for a repetition of the process.

Variations in the proportions of these constituents are seen in coals from different sources. Some coals are more free-burning, others tend toward coking. Some have high percentages of ash, others less. Differences as to clinkering or non-clinkering are noted. Such variations at once emphasize the fact that no one stoker and furnace can be suitable for all coals. Stokers and furnaces adapted for progressively burning certain coals must be modified if they are to be used for burning other coals having widely different proportions of characteristic constituents.

Free-burning coals burn best when the fuel bed is undisturbed; coking coals demand fuel-bed agitation. High-ash coals demand continuous scavenging of refuse from the grate; with low-ash coals this is not necessary. Clinkering coals must not be agitated, or clinker formations will result. With non-clinkering coal, agitation has a less detrimental effect.

Chain grates were first developed to burn high-volatile, free-burning, high-ash, clinkering coals. For such coals they offer in best form the specific combustion treatment demanded by their characteristics. The fuel bed is undisturbed, making this stoker type suitable for free-burning and clinkering fuels. The ash is continuously discharged from the grates, which is necessary for continuous operation with high-ash coals.

The development resulting in the modern chain grate has been gradual but definite, and has involved the successful burning of many coals having far different characteristics. All successes, however, have been dependent upon the application of the principles of progressive combustion. Coal burning in any practical process involves some losses: a total conversion of the heat in coal into heat in steam is impossible. Costs of operation must also be considered. These facts determine that every combustion process must finally operate with a common-sense balance between the three important factors in steam-generation economy: namely, maintenance, efficiency, and capacity.

Maintenance and Efficiency

Maintenance and reliability are closely related. The chain grate, with two-thirds of the grate surface out of the furnace and with a simple driving mechanism, was always low in maintenance costs. In the earlier designs, however, some parts were exposed both to heat and wear. Parts necessarily exposed to wear or strain often did not have sufficient resistance.

The chain, which is the fuel-carrying part, is now subjected to but slight heating as a result of adequate ventilation. Stoker frames are not subject to wear and are not exposed to heat. When exposed to heat or wear, replaceable parts are provided.

The high fuel costs of recent years, combined with a broader knowledge of combustion principles, have led to the development of features for improving efficiency. Inasmuch as chain-grate stokers have always involved very low auxiliary power consumption—about 0.5 hp. per stoker—all results obtained are practically net, and little improvement could be hoped for in that direction. Efforts were therefore directed toward the elimination of other losses, such as excess air, and to the reduction of furnace and ashpit losses.

Improvements in Grate Design

Air Leakage. A grate surface moving through a furnace presents the problem of air seals along the sides of stoker and at the rear. The reduction of air leakages at these places has contributed materially to modern economy.

Overhanging bridge walls and water backs are necessary. All attempts to approach efficient combustion without water backs have failed. Many designs of water backs were tried, resulting finally in the modern water back connected into the pressure circulation of the boiler. Water backs are successful only to the extent that they close the openings and eliminate air leakage between the bridge wall and the fuel bed.

Ledge plates or seals along the sides of the stoker went through a similar development, resulting in the modern adjustable ledge plates for making a proper rubbing seal with the stoker chain, and including means for adjustment to keep this seal intact.

The development of the ledge-plate flange adjustable against the side of the upper chain made it possible to raise and lower the stoker to vary the discharge opening under the water back in order to meet broad changes in fuel conditions. The improved results thus obtained indicated the desirability of a water back adjustable as to height, and several designs were developed. These were for the most part difficult to construct or to maintain. From such designs the modern fuel retarder was developed. This is an adjustable member in connection with a fixed water back and bridge wall.

[1] Chief Engineer, Under-Feed Stoker Co. of America, Detroit, Mich. Mem. Am.Soc.M.E.

[2] Chief Engineer, Green Engineering Co. Mem. Am.Soc.M.E.

The fuel retarder can be raised or lowered to make a definite air seal with the fuel bed.

Sifting of coal through the grate often amounted to from 5 to 10 per cent of the coal fired. The use of longitudinal skids to carry the chain in place of cross-rollers has reduced the siftings to 1 or 2 per cent, and in addition to labor saving a more uniform fuel bed results.

Furnace Design

Simultaneous with the development of the stoker has been that of furnace design. Furnace volumes have been quadrupled during the last 10 years. Modern chain-grate furnaces have 2 cu. ft. of furnace per developed horsepower. Losses due to unburned hydrocarbons have been greatly reduced. Formerly a rating of 150 per cent was exceptional. However, modern high-set arches with ample draft and adequate furnaces permit high combustion rates and high ratings from boilers.

Improved furnaces, proper draft, longer arches, water backs, and fuel retarders have all contributed to the reduction of ashpit losses. High stoker and furnace efficiency is dependent, not on a minimum of any one loss, but on a minimum sum of the losses due to excess air, ashpit loss, and unburned hydrocarbons. The modern chain grate and furnace permit adjustment and continuous operation, with the aggregate of these losses a minimum.

Chain grates are ideally adapted for producing smokeless combustion, due to the uniform feed, uniform fuel bed, and the arch. With modern furnaces and proper air control, smokelessness within the capacity of the furnace can be assured even with the high-volatile smoky coals of the Middle West.

Capacity

Modern steam turbines called for greater capacities from boilers. This demand was met in the chain-grate field by development along three general lines: namely, higher drafts, larger grate surfaces, and forced draft.

Higher Drafts. Chimney heights for natural draft were increased to 200, 250, and even in excess of 300 ft. Many plants installed induced-draft fans. Furnace drafts of 0.50 to 0.60 in. were obtained, and combustion rates reached figures of 40 to 45 lb. per sq. ft. of grate surface per hour.

Larger Grates. This rate of combustion seems to be about the limit of natural-draft performance. Efforts to obtain higher ratings have led to larger stokers. Stokers were built up to 18 ft. long, with ratios of grate to heating surface increased to 1 to 30. With such grates and high draft, boiler ratings up to 200 per cent were possible.

Forced Draft. The need of still higher ratings, particularly with low-grade coal, brought the application of forced draft to the chain grate. Early installations applied forced draft at uniform pressure under the entire grate surface. This increased capacity but did not control excess air. Forced draft under a fuel bed with the slightest tendency toward thin spots caused excess-air losses, chilled the furnace, and reduced capacity.

The logical development for air control was to divide the stoker into compartments and control the air supply to each compartment.

The forced-blast chain-grate stoker has been in commercial use for some twenty-five years, and in successful use for approximately ten or twelve years in the anthracite-coal regions, but it was not until five or six years ago that any really successful installations were made for burning bituminous coal.

This stoker consists of a continuous or endless chain of links or grate bars traveling over front and rear sprockets. Side girders are used in some cases, but in others are entirely omitted and transverse members forming compartment sides and wall supports substituted therefor. Above the front sprockets is a sizeable coal hopper, and at the back of this hopper a stoker gate which can be raised or lowered to vary the thickness of the fuel bed on the grate.

The stoker is usually set in an extension or Dutch-oven furnace the arch of which radiates its heat on the incoming fuel under the stoker gate and causes i to ignite, the fire gradually burning down through the fuel bed until it reaches the grate. The thickness of the fuel bed is governed by the character of the coal burned, the length of the stoker grate, and the capacity at which the stoker is to be operated. With the same grate, and with different grades of coal or different capacities the fuel bed may vary between 5 in. and 9 in. in thickness.

Size of Forced-Draft Stokers

The length of the stoker, which should be taken as the distance between the inner face of the stoker gate and the sealing plate of the rear blast compartment, is varied somewhat to conform with the type of boiler under which the stoker is installed, and with the rate of combustion which is desired. Very few forced-draft chain grates are less than 12 ft. in length, but only in exceptional cases do they exceed 20 ft.

The width of the stoker is usually made slightly less than the boiler-furnace width, so as to afford column protection. Single stokers practically the full width of the furnace have been built, even for the wide central-power-station boilers now so popular. There are forced-blast chain-grate stokers in operation today that are 24 ft. in width, and widths of 27 ft. to 30 ft. are under consideration.

Various types of links are used with the forced-blast chain-grate stoker. Regardless of the type, however, the design of the link is such that relatively fine jets of air are admitted through the grate, and a uniform air distribution is applied to the fuel bed from any given blast compartment.

The forced blast is usually admitted into five or six compartments formed between the runs of the chains. These compartments are sealed from one another, and dampers or slides are arranged so that the blast to any one compartment may be regulated independently of that in any other. Some designs are so constructed that any compartment can be operated on forced or natural draft, or closed off entirely, and so that the change from one to either of the other conditions of air supply can be made simply by the operation of a single adjustment lever.

As the coal is burned, the resistance of the fuel bed decreases toward the rear end of the grate, and the air pressure is varied in the different compartments to meet the requirements and effect proper combustion at any given point with the least excess air. It is possible to use only half or three-quarters of the grate length when operating the stoker at low capacities and still maintain a comparatively high rate of combustion on the front portion of the stoker.

The blast pressure in any one compartment rarely exceeds 2 in. water pressure, even at a combustion rate of 55 to 60 lb. of coal per sq. ft. of grate surface. Low-pressure designs obtain similar combustion rates with about one-third of this pressure. The highest pressure is usually carried in the second and third compartments from the front of the stoker, as it is at these points that the fuel bed on the grate is completely ignited and the maximum rate of combustion takes place.

The blast to each compartment is regulated by heat control. The amount of blast used under the grate and the speed at which the stoker chain travels are the factors that usually determine the capacity at which the stoker may be operated with a given thickness of fuel bed.

Combustion Arches

Stokers installed for the burning of the Central States high-volatile coals have ignition or combustion arches set about four feet above the grate at the front end, and somewhat higher at the inner end. These arches cover approximately 50 per cent of the length of the stoker, are of the suspended type, and are made from high-grade refractory material.

Stoker installations for the burning of the low-volatile high-carbon bituminous coals of the Eastern States use a shorter arch, covering about 30 per cent of the stoker length but set at practically the same height above the grate as for the high-volatile coals. Arches set at this distance above the grate require a short ignition arch, 12 to 18 in. in length, at the stoker gate, and set 18 to 24 in. above the grate. The increased rate of combustion obtained with forced-blast chain grates necessitates a better grade of refractory for the entire furnace lining.

Various schemes are being considered today for cooling the furnace side walls of all the different types of stokers operating at high rates of combustion, with the purpose of reducing furnace

maintenance costs. Of these various schemes those employing water-cooled members will undoubtedly prove the most successful, because of positive functioning.

Prevention of the formation of clinkers at the fire line on the side walls is a problem separate and distinct from reducing side-wall maintenance. Some manufacturers are using specially designed firebrick blocks at the fire line, through which blast from the blast duct enters the furnace. The air passing through these blocks keeps them cool and prevents clinker from adhering to them. Other manufacturers are using side-wall water boxes at this point, some of which are connected into the boiler circulation, while others are independently connected.

The bridge-wall water back is a part of the standard stoker equipment with several of the forced-blast chain-grate stokers. This water back is carried transversely across the rear end of the stoker 3 to 7 in. above the grate, and acts not only as an air seal at this point but protects the bare links of the stoker from the reflected heat of the bridge-wall brickwork.

TABLE 1 FUELS USED AND RESULTS OBTAINED IN ELEVEN BOILER PLANTS EQUIPPED WITH CHAIN GRATES

Description of Station	Location	Name of Coal Used	Moisture, per cent	Ash, per cent	Volatile, per cent	Fixed Carbon, per cent	Sulphur, per cent	B.t.u. per lb., Commercial Basis	Average Rating, per cent	Maximum Rating, per cent	Banked Boiler Hours, per cent	Economizers	Combined Efficiency of steam-generating unit, per cent	Time covered
Central station [1]	Middle West	Illinois	14.5	16			4	10000	225	275	8	Yes	73.6	3 months
Central station	Middle West	Illinois	14.5	16			4	10000			30	50 %	69.1	3 months
Central station	Southwest	Kansas	4.66	11.7	33.05	50.62	4.2	10561				No	69.4	24 months
Central station	West	Iowa	16.51	18.72				8891	180		32	No	73	12 months
Central station	Middle West	Indiana	9.8	17.7	33.3	49	4.2	10000	170	230	30	No	70	12 months
Steel plant	Middle West	Indiana	18	12.2	35.2	52.6	2.20	10150	140			No	71	12 months
Steel plant	Pittsburgh district	Pennsylvania	2.09	10.5	33.7	55.8	1.60	13250	107			No	69.4	12 months
Central station	West	Colorado	23	12.5	32.5	32	0.20	8865				Yes	72	1 month
Central station	West	Kansas	6	19	27	48		10700	130	200	49	50 %	69	1 month
Central station	Middle West	Ohio&Penn.						11766	145	225	6	Yes	73.8	5 months
Central station [2]	Middle West	Illinois	14.5	16			4	10000	271			Yes	78.7	1 month

[1] Part of the stokers in this plant are forced-draft units.
[2] All of the stokers in this plant are forced-draft units.

Results Secured

The forced-blast chain-gate stoker is particularly adapted to the use of free-burning coals that require agitation of the fuel bed to break the crusting or caking action so often encountered with the slower-burning coking coals.

With free-burning coals, which usually run high in sulphur and have an ash with a low fusing point, results are being obtained, with uninterrupted operation, that equal the results obtained with other types of stokers using the low-volatile high-carbon coals.

When burning No. 3 buckwheat or coke breeze, fires 3 to 6 in. in thickness are carried on the grate and sufficient blast is carried in the first and second blast compartments to cause a gentle boiling or dancing of the fuel bed. Care must be taken, however, to regulate the thickness of fire and the blast so that excess carbon monoxide is not produced and continued combustion carried through the boiler to the chimney.

The forced-blast chain grate may be operated at continuous high overload capacities for days at a time with only slight variations in the steam output of the boiler. This operation is made possible by the uniform thickness of the fuel bed, the uniform blast pressures carried, and the uninterrupted disposal of ash and refuse from the grate. Such stokers may be operated efficiently under natural draft when burning as little as 10 lb. and as high as 35 lb. of coal per sq. ft. of grate per hour. Forced-draft combustion ratings reach 55 to 60 lb. of coal per sq. ft. of grate per hour.

The forced-blast chain grate is simple to operate and flexible in handling varying load conditions. If properly handled it can be brought from banked fires to full load in time to meet any ordinary power-plant requirements. A cold boiler can be put on the line in 45 min. from the time of lighting the fires. The boiler can be operating at 150 per cent of rating in 5 min. from the time it goes on the line, or it can be operating at 200 per cent of rating in 7 min.

With the ordinary short-banked fire, which consists of a bed of coal three to four feet in from the stoker gate, the remainder of the grate being bare, the boiler can be brought up to 200 per cent rating within 25 min., while with the long bank, in which 50 per cent of the grate is covered with fire, the boiler can be brought up to 200 per cent rating within 6 to 8 min.

Automatic control has been successfully applied to both natural- and forced-draft chain grates. With natural-draft chain grates the usual control is by means of a steam-pressure or steam-flow regulator controlling the boiler damper and the speed of the stoker engine or motor. With forced-draft chain grates several control systems are in successful service. The electrical control is applicable on motor-driven installations. The steam-flow regulator controlling the air supply to the stoker and the speed of the grate is giving successful results.

The steam-pressure regulator controlling the air supply to the stoker and speed of the grate is also giving excellent service. In case constant furnace draft is desired, the balanced control can also be applied, as is frequently done with the two latter-mentioned systems.

Natural Draft vs. Forced Draft

Whether natural- or forced-draft chain grates should be installed depends upon the conditions in the individual plant. The station load, banking periods, boiler absorption with or without economizers, as well as the limits of the draft available, are all involved.

Natural-draft chain-grate stokers, within the limits of the draft available, produce cheap steam. Low auxiliary power requirements, low maintenance, and controlled loss in the combustion process, make low cost of steam inherent.

Natural-draft stokers should be installed:

a Whenever the capacities demanded to meet the station load are within range of the natural draft available

b Whenever the load demand is steady or where peaks can be anticipated sufficiently far ahead to permit building up furnace conditions to meet them

c Within the limits of the above two conditions, whenever induced draft and economizers are used.

In Table 1 the author submits some long-period operating figures from chain-grate power stations. While the compiling of such figures by power stations is subject to variations in the methods employed for that purpose, the figures in question nevertheless must be accepted as part of the operating records of large and reliable companies having engineering departments competent to compile such records.

Overfeed Stokers of the Inclined Type

By GEO. L. BOUTON,[1] DETROIT, MICH.

In this paper the author discusses the development, present construction, and method of operation of the front- and side-feed types of inclined overfeed stokers. Several side-feed stokers are described, with an illustration of a Dutch-oven type of setting. It is stated that 200 per cent of boiler rating can be obtained with 0.3 in. to 0.5 in. draft loss through the fuel bed, and that when forced draft is applied, it should be done with proper regard to air circulation and the maintenance of suction above the fire. Front-feed stokers are also described, with an explanation of combustion control by varying the stroke of the coal pusher and the angle of rotation of the bars. The effect of the flux content of ash in determining the fusion temperature is also discussed.

STOKERS of this type are of two general classes, the side-feed double-inclined or V-type, and the front-feed or single-inclined stoker. The early development of these stokers was along natural-draft lines, because that was the draft available and because it was possible to readily burn all the coal required to meet load conditions. As the steam plants have increased in size, the boilers and stokers have also increased in size until this type has apparently reached a limit in a stoker having a projected grate area of 100 to 110 sq. ft. in a single unit, capable of burning sufficient coal, under forced draft, to develop about 2000 b.hp. as a maximum.

The double-inclined side-feed stoker was the first to make its appearance in this country, Thomas Murphy fathering this particular line of development, commencing about 1875. His first attempt, which was hand-operated, was placed in the firebox of a marine boiler and had inclined grates, every second grate being movable. It was provided with a revolving toothed cylinder or clinker grinder extending from front to rear along the bottom of the V, for the removal of clinker and ash.

In 1879 Murphy moved this device forward into a Dutch oven for use in connection with a return-tubular boiler, and added magazines and stoker boxes for feeding coal to the upper end of the grates. He placed a firebrick arch above the entire grate surface, with a second arch enclosing an air space above the arch and with provision for circulating air for combustion over the firebrick arch and through openings in the arch plates immediately above the fire, at the point where the volatile gases are distilled from the coal. About 1880 he provided an engine drive, placing a reciprocating bar across the front of the stoker, with arms and links to operate the stoker shafts which moved the stoker boxes back and forth, and the rocker bars which raised and lowered the movable grates, and with a ratchet which rotated the clinker grinder. In all essential features this stoker is the stoker of this class of the present time, as represented by the Murphy, Detroit, and Model stokers, although there are many minor changes in the stokers as built today.

About 1885 the front-feed inclined stoker was developed, the Roney and Brightman stokers being brought out at that time. The Brightman stoker was apparently not a financial success and it gradually disappeared; a modified form of it, however, still remains in the Wetzel stoker.

Originally the grates in the side-feed stokers were set at an angle of 35 deg. with the horizontal. As the size of the stokers was increased this angle was increased to 40 deg., and later to 45 deg., which is the present standard. Grates at this angle are suitable for bituminous and semi-bituminous coals. With non-coking coals a much flatter grate is desirable, and when coals of this sort are to be burned it is advisable that the stokers be designed particularly for the coal in question. The grates in the Roney stoker are at an angle of 35 deg. with the horizontal, and this stoker will burn anthracite and bituminous coal and lignite. The grates in the Wetzel stoker are also set at the same angle.

Where wood refuse or spent tanbark is used, this is usually burned in connection with bituminous coal, enough coal being burned to keep the grate surface covered. Wood refuse is spouted to the stoker through an opening in the stoker front, or dropped through openings in the arch directly on to the fuel bed. Tanbark is usually mixed with the coal and fed to the stoker in the regular way, that is, through the magazine or hopper. Spent tanbark will run about 60 per cent moisture, and when a half-and-half mixture is used about 85 per cent of the heat supplied to the boiler will be from the coal, the remainder from the tanbark.

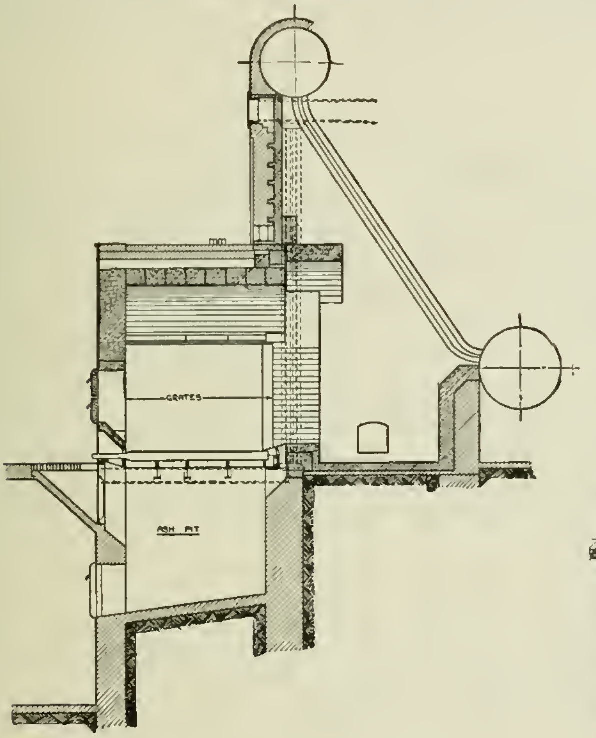

Fig. 1 Typical Dutch-Oven Setting for Side-Feed Double-Inclined Overfeed Stoker under a 500-Hp. Stirling Boiler

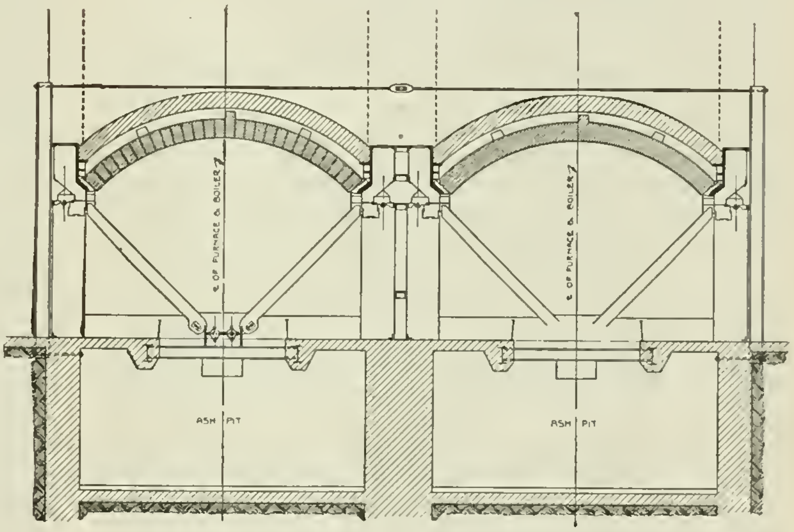

Fig. 2 Typical Dutch-Oven Setting for Side-Feed Double-Inclined Overfeed Stoker under a 500-Hp. Stirling Boiler

Side-Feed Double-Inclined Stokers

The side-feed double-inclined stoker may have either a flush-front or Dutch-oven setting. The flush-front setting is limited to the smaller return-tubular boilers and horizontally-baffled water-tube boilers. On the larger return-tubular boilers, vertically baffled horizontal water-tube boilers, and boilers of other types it is advisable to place the stoker in a Dutch-oven setting. A Dutch-oven setting materially simplifies the matter of supplying coal to the stoker, and where desirable an eight or ten-hour supply of coals can be stored on top of the stoker. A typical Dutch-oven setting is shown in Figs. 1 and 2.

[1] Chief engineer, Murphy Iron Works. Mem. Am.Soc.M.E.

These stokers are made in various sizes, both as to width and depth, varying from a stoker with a grate surface 4 ft. wide and 3 ft. deep to one having a grate 12 ft. wide and 9 ft. deep. In the larger stokers 1 sq. ft. of projected grate is provided for each 6 1/4 rated horsepower of the boiler, and in the smaller stokers 1 sq. ft. for about each 5 rated horsepower. Where the stokers are set with a Dutch oven they extend in front of the boiler about the depth of the grate surface of the stoker, this being varied to suit local conditions and the details of the boiler. The overall width of the stoker is roughly the width of the boiler setting. The head room required will vary with the width of the stoker. The boiler should be set sufficiently high so that the front header or the sill of the tube-door opening clears the top of the arch about 3 in. This would mean a height of about 6 ft. on a 100-hp. boiler, 7 ft. 9 in. to 8 ft. 3 in. on a 300-hp. boiler, and 11 ft. 3 in. on a 600-hp. boiler. Where vertical water-tube boilers are used, such as Wickes, Rust, or Erie City vertical, it is advisable to place a combustion space between the rear of the stoker and the tube surface of the boiler. This can be made of somewhat greater cross-section than that of the stoker. The distance from the rear end of the grate surface to the tube surface should be 6 or 7 ft.

Stokers of this class are usually driven by a small steam engine operating the reciprocating bar through a chain of gearing. Where for any reason it is desirable to do so, a motor, either a.c. or d.c., can be used in place of the engine. An engine is preferable to a motor, however, as the exhaust steam which it supplies is useful under the clinker grinder.

As far as the author knows, the most convenient and effective means of chilling clinker so that it can be readily handled is by means of low-pressure steam discharged under both the clinker grinder and the lower ends of the grates.

It is desirable that the fuel be fed as uniformly as possible to the stoker. The fuel bed is about 8 to 10 in. thick at the upper end of the grates, thinning down gradually toward the clinker grinder. Minor fluctuations in load should be taken care of by minor variations in the draft over the fire. Where the load changes into a decidedly higher or lower range, the coal feed should be increased or diminished to meet this range, the draft over the fire being regulated to take care of the immediate needs of the boiler.

The draft loss through the fuel bed will vary with the amount and kind of coal being burned, the high-volatile coals requiring less draft than the lower-volatile coals. The amount of draft required is also affected by the amount and kind of ash which the coal carries. Where proper draft is provided, stokers of this class will take care of various loads readily up to 200 or 225 per cent of boiler rating, although the draft available usually limits the capacity to 200 per cent of boiler rating or less. Where there is a shortage of draft it is possible to compensate for this in part by increasing the amount of "rousting" or hand manipulation of the fuel bed. At two per cent of boiler rating the draft loss through the fuel bed will vary from 0.3 to 0.5 in. water gage, depending on the kind of coal and the amount of rousting.

Where it is desired to obtain more capacity than can be obtained with the natural draft available, it is sometimes possible to do this by adding forced draft. Where forced draft is applied to a stoker of this class, it is advisable to see that all the necessary items for its proper installation are taken care of. The air should be admitted to the space beneath the grates, either at the front or the rear, in a line parallel with the clinker grinder; two inlets being used, placed symmetrically with reference to the center line of the stoker. Instances have been found where a blower has been placed through each side sheet, discharging air directly against the grates, and troubles have quickly resulted from such practice. Under natural-draft conditions the amount of air reaching the furnace through the openings in the arch plates increases as the capacity increases, and provision should be made so that this same condition holds good under forced-draft conditions.

The limit of capacity under forced-draft conditions will be that point where the draft over the fire is so reduced that fire is blown out of various openings. This will be when the draft over the fire is reduced below 0.10 in., probably to about 0.05 in.

With forced draft properly installed and skilful firing it is possible under favorable conditions to get in the neighborhood of 300 per cent of boiler rating. The fires are rather thin for forced-draft work and it requires closer attention to the fuel bed to keep the grates covered than in the case of stokers using a much thicker fuel bed.

Where these stokers are operated under natural-draft conditions the proper method of regulating the air supply is by adjusting the damper at the outlet of the boiler. This can be done by hand where necessary. There is no objection to using a damper regulator provided it reproduces the action of a skilled fireman as closely as possible and shifts the damper slightly with varying steam pressure.

Front-Feed Inclined Stokers

Of the many forms of front-overfeed inclined stokers which have appeared, the Roney and Wetzel are still being built. The Roney is a natural-draft stoker only. It is made up of an inclined grate with transverse bars. Each bar is supplied with sectional grate-bar tops so arranged that they allow a uniform distribution of air through the whole grate area. At the upper end of the furnace, flat fuel plates are provided on which the coal can coke, and this prevents sifting of the green coal until the coking process is well under way; by this time there is no further trouble with siftings. There is an agitation given to the grates by a rotary motion of the transverse bars. This motion feeds the refuse and fuel uniformly toward the lower end of the grates. At this point and immediately above the dump grates there is an agitator for the purpose of breaking up clinker that may form in this zone; it also serves the purpose of preventing the avalanching of the fuel bed down the grate while the dump grates are open and the fire is being cleaned. The dump grates are slotted, thus providing active fuel-burning surface in this zone.

The angle of rotation of the transverse bars can be varied from nothing to a maximum. The stroke of the coal pusher can also be varied. The ability to control these motions without changing the speed of the engine provides a very wide range of flexibility. It is customary practice to operate Roney-stoker driving units at constant speed, and take up the fluctuation in the rate of feeding coal by means of the variable adjustments on the stroke of the coal pusher and grates. Motors or reciprocating engines are usually supplied for driving Roney stokers. The whole stoker-driving mechanism is extremely simple, as a multiplicity of stokers can be driven from one shaft for both the feed and grate motion.

The thickness of the fuel bed on a Roney stoker is uniform for a given grade of coal and does not vary for different ratings. The best practice is to control the rating on the boiler as desired by means of the boiler damper and not by thickening or thinning the fuel bed.

The Roney stoker is applicable to any type of boiler. It is set with an arch to ignite the incoming fuel and burn the volatile gases. This stoker is suitable for burning anthracite and bituminous coals and lignite. For burning anthracite and lignite a slight change is made in the grate-bar tops so that they will overlap in any position and thus prevent the fuel from sifting through. There are a number of installations where hog fuel has been burned very successfully in conjunction with coal. This is done by using an extension furnace and cutting a hole through the arch so that the hog fuel can be dropped through the arch and on the fuel bed.

The Wetzel stoker is somewhat similar to the Roney, the principal difference being in the form of grate used. Instead of being made up of bars extending across the furnace and rocking, the grate is made up of a series of bars extending from front to rear. These bars are ribbed to prevent sifting; the upper end of the grate is supported on a short rocker arm so that is has a slight forward-and-back motion, and the lower end on an arm placed at a somewhat different angle, so that the motion of the lower end of the grate is practically at right angles to the grate surface.

Ash

Most coal ash has a fireclay base with various kinds and amounts of foreign materials which act as fluxes, such as iron, lime, magnesia, and sodium and potassium oxides. An ash low in fluxes is desirable because it will be an ash of high fusing temperature and one which can be handled in a stoker more readily than an ash high in fluxes. It is also desirable when the maintenance of the stoker and boiler brickwork is considered, as small particles of ash impinge on the brickwork, and the iron, lime, etc., in the ash form an active flux for this firebrick at furnace temperatures.

The Design and Operation of Underfeed Stokers

By H. F. Lawrence,[1] Philadelphia, Pa.

This paper describes briefly the distinctive features of the single- and multiple-retort types of underfeed stokers, giving particulars regarding their operation and results that have been obtained. Emphasis is laid on the importance of proper adjustment of the secondary coal feed, to prevent clinker and ash depositing at the lower end of the retorts, and on draft control not too responsive to momentary variations in boiler conditions. Underfeed stokers are said to be particularly adapted to bituminous and semi-bituminous coals, and for carrying sudden overloading. Clinkers are a necessary result of the high temperatures secured, and different means for preventing their adhesion to the side walls are discussed. The relative merits of various fans are considered, and a table of setting heights is given.

Underfeed stokers are so designed that coal is fed from beneath the burning fuel. This is accomplished by feeding through retorts with adjustments so that the fuel bed is replenished throughout the length of the retort. The main feed from the coal hopper is accomplished with rams of fixed displacement so that the amount of fuel fed per stroke is a definite amount for a given coal, and therefore the amount fed per hour is accurately controlled by regulating the speed at which the rams are operated.

Single-Retort Stokers

The first development of this type was the single-retort underfeed stoker. This consists essentially of a horizontal retort, into which fuel is fed from the hopper and distributed throughout the length of the retort. Tuyeres are placed around the edge of the retort and through these air is supplied to the fuel under pressure from a fan. Dead plates or dump plates are placed on each side of the retort, from which the ash and refuse are removed. For wider furnaces, intermediate inclined movable grates or tuyeres are placed between the retorts and the dump plates. These serve the purpose of providing more grate surface and also of depositing the ash and refuse on the dump plate.

Single-retort underfeed stokers do not require large ashpits and ash tunnels below the boiler-room floor. They are cleaned of ash and refuse by dumping into shallow ashpits which are depressed slightly below the floor line, and withdrawing the ash and refuse through doors in the boiler front at floor level, or by withdrawing the ash from the dead plates through doors in the boiler front.

These stokers are also particularly adaptable to installations in which more than two boilers are placed in a battery, since side doors are not necessary to their operation. Boiler plants may then secure the advantages of the underfeed type of stoker without the expense of excavation and without being limited as regards arrangement of boilers.

Multiple-Retort Stokers

The multiple-retort stoker is a development of the single-retort and consists of a number of single retorts placed close together and inclined with the ash discharge at the rear. As the coal is burned the ash is formed on top of the fuel bed and is floated to the rear and deposited on dump plates or into crusher pits from which it is readily removed. The continuous ash discharge consists of rotary toothed crushers placed at the rear of the stoker and set low so that a large, deep pit is formed for receiving the ash and burning out the last of the combustible material.

The secondary coal feed, that is, the feed from the retort to the fuel bed, is obtained in various ways. The Taylor stoker uses additional rams similar to the coal-feeding ram, which are placed in the bottom of the retort. The retort inclination is such that the rams are reciprocated horizontally. The Westinghouse and the new Frederick stokers have a lesser inclination, and the secondary coal feeding is accomplished by large wedge-shaped castings placed at the bottom of the retort. These are reciprocated on an inclination corresponding to the slope of the bottom of the retort.

The Jones and Detroit stokers have similarly shaped retorts, and the secondary coal feed is obtained by small wedge-shaped pushers which are reciprocated horizontally in the bottom of the retort. The Riley stokers accomplish the secondary feeding by reciprocating the retort sides and the tuyeres. They also vary in the angle at which the tuyeres are placed—from horizontal in the case of the Detroit to 25 deg. in the Taylor stoker.

Tuyeres are placed between the retorts, and serve to convert the static head of air into velocity and direct the flow of air through the fuel bed. The tuyere designs naturally are different in each stoker.

All designs are for forced draft and cannot be operated at any appreciable capacity with natural draft. The air for combustion is circulated beneath the furnace parts and thereby cools these parts before being discharged through the fuel bed.

Operation of Underfeed Stokers

The operation of underfeed stokers is essentially as follows. The incandescent burning fuel is on top and is replenished throughout the entire retort length from beneath. As the coal emerges from the retort it is coked and spreads over the tuyeres, forming a homogeneous fuel bed across the entire furnace width. As the fuel approaches the surface the volatile matter is completely distilled off and the fuel completely coked. The surface consists of a layer of incandescent burning coke. The air for combustion is introduced near the point where the fuel emerges from the retort. As the volatile gases are liberated they are thoroughly mixed with air. As the mixture passes up through the fuel bed, higher-temperature zones are reached and complete combustion of the volatile gases takes place when they pass through the white-hot coke at the surface.

Smokeless combustion is obtained without the use of special mixing of ignition arches or special brickwork construction. As the fuel bed is replenished from beneath the surface, the burning incandescent coke which is on top is slowly moved toward the dump plates. As the ash is formed it is floated on the surface and is eventually deposited on the dump plates.

The control of the fuel bed is obtained by adjustments of the secondary coal-feeding arrangement. For good operation it is essential that the fuel bed be so controlled that the replenishing coal emerges from the retort through its entire length; the lesser amount being fed from the rear end of the retort.

With low-grade western coals more fuel must be discharged from the rear end of the retort than with the high-grade eastern fuels. In general, the greater the quantity of ash in the coal, the longer should be the stroke of the secondary fuel-feeding mechanism.

If insufficient coal is fed from the lower or rear end of the retort, the ash, instead of being carried on to the dump plates, is deposited at the lower end of the retorts, and as high fuel-bed temperatures are always obtained the ash is clinkered, and when deposited at this point it blocks the air discharge. After a short interval, fuel from the upper part of the retort, which is not coked, is deposited over this clinker formation and then avalanches on to the dump plates. With this condition of fuel bed it is impossible to secure good results or good operation. With proper strokes of the secondary coal-feeding mechanism this condition can be eliminated, as with the proper amount of coal being fed from this section of the retort the ash and clinker can never be deposited at this point. This is really the important adjustment to be made for various grades of coal, and it probably receives less attention from plant operators than any other variable. When properly adjusted the fuel bed is automatically maintained clean, and high rates of combustion can be obtained.

With the underfeed stoker properly adjusted, fresh fuel will be fed up throughout the full length of the retort. Green fuel moving upward with respect to the tuyeres tends to keep them buried, and consequently the ironwork is in the comparatively cool zone of the fuel bed. For this reason the maintenance is low on underfeed stokers.

With the underfeed system of combustion the excess air re-

[1] Mechanical engineer, American Engineering Co. Mem. Am.Soc.M.E.

quired can be reduced to a minimum, which means that high fuel-bed temperatures are obtained. The fuel-bed temperature will probably always exceed the ash-fusion point of any of our coals. This means that clinker must be formed in order to secure the best combustion results.

Results Secured

These stokers are particularly adapted for burning bituminous and semi-bituminous coals. However, with only slight modifications lignites and coke breeze are also burned with excellent results.

With the thoroughly coked thick fuel beds carried, this apparatus is very quick in responding to load demands. Under running

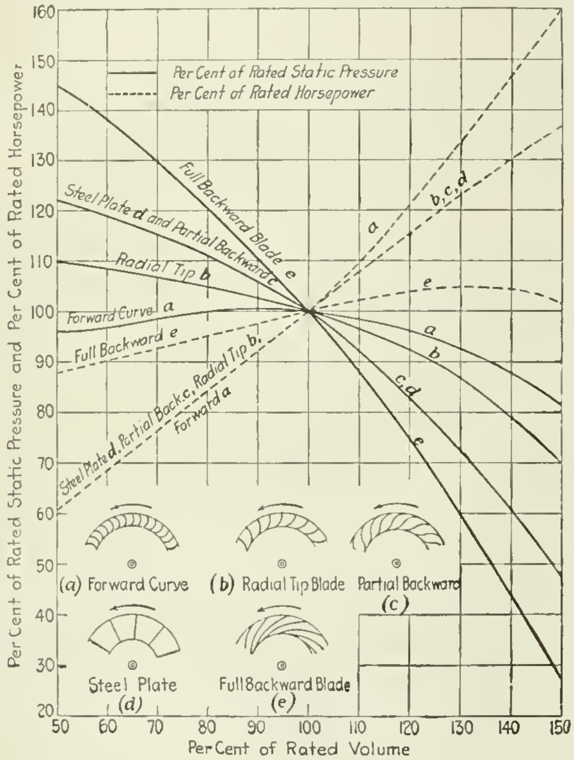

Fig. 3 Fan Characteristics at Constant Speeds

conditions the boiler capacity can easily be doubled almost instantaneously. From a banked-fire condition loads equivalent to 200 per cent of boiler rating and over can be picked up in a few minutes.

Many times the stoker manufacturer is handicapped by being forced to meet space limitations of the boilers. It is recommended that stokers be selected first, of the proper size and type to obtain the desired results, after which the boiler should be selected to meet the furnace requirements of the stoker.

Regulation

Automatic regulation is receiving a great deal of attention at the present time, and improved equipment has been developed which is giving good results. It is doubtful, however, whether regulating apparatus will ever be developed to the point where adjustments will not be required from time to time. These adjustments, it may be said, should only be made by an expert observer or fireman.

An ideal equipment would control all the variable elements in the proper proportion, thereby obtaining a constant steam pressure. It would, in addition to controlling the fuel, air supply, and drafts, be required to control the feedwater in proportion to the load.

Practically all regulating systems in use at the present time are controlled by variations in the steam pressure. The damper regulator is very sensitive to slight changes in steam pressure, and unless its action is retarded by some means, hunting will take place, causing rapid and wide variations in the air pressure. Much better fuel economy is obtained by eliminating the rapid fluctuations in air pressure. This is accomplished by damping the regulator so that a greater steam-pressure variation is required to operate it through its complete stroke.

The Jones fluid-operated rams are controlled by a Cole automatic valve for each cylinder. This valve is operated from a power source, usually driven from the fan or the fan engine. It is possible to obtain a number of different adjustments for the rate of turning this automatic valve, so that the rate of feeding fuel can be varied for each retort; in fact, all the retorts can be arranged to feed at one speed or at eight different speeds. Furthermore, each valve can be operated by a hand crank, so that the coal can be fed into the retort in very large quantities at any time it is required.

Fans

There are several types of fans used in stoker service, each of which has different characteristics.

The full-backward-curved fan with long blades, Fig. 3 (*e*), which is also a high-speed fan, has the best characteristics for stoker service. It has a very steep static-pressure curve, together with a comparatively flat horsepower curve, and has the additional characteristic that after reaching the maximum horsepower any further increase in volume due to reduction of static pressure, will reduce the horsepower required. The smallest-sized motors can be used safely on this type of fan, and it also has the highest efficiency.

For a fan operating against a constant resistance the power varies as the cube of the speed, the static pressure as the square

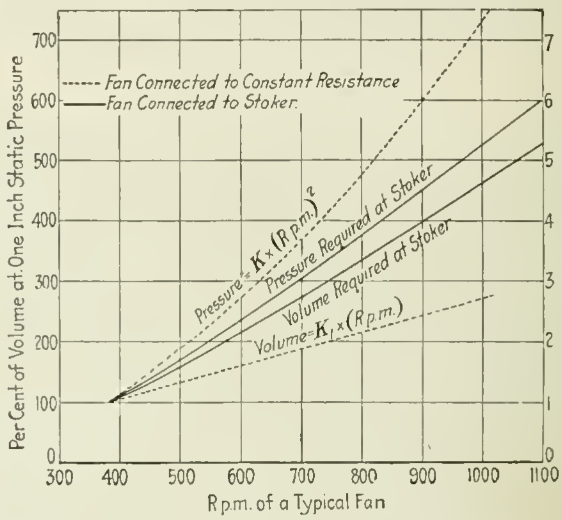

Fig. 4 Relation of Volume and Pressure of Air to Fan Speed

of the speed, and the volume directly as the speed. In underfeed-stoker practice, however, the resistance is not constant, so that the fans do not follow this law.

Fig. 4 shows in the dotted curves the volume and pressure characteristics in accordance with the constant-resistance law, while the full-line curves show the volume and pressure characteristics at the stoker connection. These curves have been plotted from data obtained in actual stoker tests.

Clinker Prevention

The most serious operating difficulties are caused by clinker adhesion to the side walls of the furnace. There are several successful methods for preventing this, the most popular one probably being that in which perforated firebrick blocks are located along the clinker line, through which the air is blown from the stoker air duct. Care must be used in locating these blocks so that no free air is discharged above the fuel bed.

Another method of preventing side-wall clinker uses special high side tuyeres through which air for combustion is discharged, these tuyeres extending high enough along the side walls to prevent the clinker adhesion to the brickwork.

Still another method which has been very successfully applied in a number of plants, is one in which cast-iron side-wall air boxes are used. These faces of the boxes toward the fuel bed are made of small overlapping ribbed plates. These plates are solid so that no air is discharged through them. Air enters one end of the box from the stoker air chamber and is discharged under the tuyeres from the other end of the box; this air circulation being sufficient to prevent burning of the plates and the ad-

TABLE 2 SETTING HEIGHTS FOR VARIOUS TYPES OF BOILERS EQUIPPED WITH STOKERS

(Min. = absolute minimum; P.M. = preferred minimum, i.e., the minimum heights recommended)

	Type of Stoker to be Installed													
	Multiple-Retort Underfeed		Single-Retort Underfeed				Side Overfeed		Front Overfeed		Chain Grates			
Type of Boiler	Taylor, Westinghouse, Riley, Jones A-C		Type E		Jones Single-Retort		Murphy, Detroit		Roney		Natural Draft		Forced Draft	
	Min.	P.M.	Min.	P.M.	Min.	P.M.	Min.	P.M.	Min.	P.M.	Min.	P.M.	Min.	P.M.
Water-Tube:														
Horizontal	10′	12′	10′	12′	8′	10′	8′	11′	8′	10′	10′	12′	12′	14′
Inclined (Hor. M.D.)	7′	8′	6′	8′	6′	8′	5′	7′	6′	8′	6′	8′	7′	8′
Inclined (Vert. M.D.)	5′	6′	5′	6′	3′6″	5′	3′6″	5′	3′6″	5′	3′6″	5′	6′	8′
Vertical (Hor. M.D.)	3′	4′	3′	4′	3′	4′	3′	4′	3′	4′	3′	4′	3′	4′
Vertical (Vert. M.D.)														
150-hp.	4′6″	5′	4′6″	5′	4′6″	5′	3′3″	....	3′6″	4′6″	4′1″	4′7″	5′	5′ 6″
250-hp.	5′6″	6′	5′6″	6′	5′6″	6′	3′3″	....	3′6″	4′6″	4′1″	4′7″	5′	5′ 6″
500-hp.	6′	6′6″	6′	6′6″	6′	6′6″	3′3″	....	3′6″	4′6″	4′1″	4′7″	6′	6′ 6″
Horizontal Return Tubular:														
72-in.	8′	10′	8′	10′	7′	10′	7′	8′	6′	8′	7′	8′	8′	10′
84-in.	8′	10′	8′	10′	7′	10′	7′	9′	6′	8′	7′	8′	8′	10′

hesion of clinker. These boxes should not be less than 10 in. wide.

Carborundum bricks are satisfactory for this purpose with some coals. However, when the ash contains much iron, carborundum brick is rapidly eaten away.

TABLE 3 DEFINITIONS OF SETTING HEIGHTS FOR VARIOUS TYPES OF BOILERS

Type of Boiler	Setting Height
Water-tube, horizontal	Floor line to bottom of header above stoker
Water-tube, inclined	Horizontal mud drum: floor line to center of mud drum
	Vertical mud drum: floor line to top of mud drum
Water-tube, vertical	Horizontal mud drum: floor line to center of mud drum
	Vertical mud drum: floor line to top of mud drum
Horizontal return tubular	Floor line to under side of shell.

Setting Heights

The Stoker Manufacturers' Association, in conjunction with the American Boiler Manufacturers' Association, have adopted minimum setting heights for all types of boilers which are given in Table 2. Setting heights for the different types of boilers are defined in Table 3.

A number of recent large boiler units have been set considerably higher than as specified in Table 2. The boilers of the new Hell Gate power station are set 21 ft., giving a furnace volume of $16^1/_2$ cu. ft. per sq. ft. of grate surface, or 390 cu. ft. of furnace volume per 1000 sq. ft. of boiler heating surface.

Frequently the combustion space required is stated as a function of the coal-burning capacity. This is misleading since it leaves out of consideration all conditions imposed by the arrangement of the boiler baffles and stoker in relation to one another.

It is desirable to keep the velocity of the rising gases in the furnace as low as possible, but a larger horizontal furnace section, with consequent large volume, may not necessarily do this.

Ample height of the boiler above the stoker should be secured in order that combustion of the gases may be completed before they enter the tubes.

High setting heights impose a more severe service upon the brickwork. Extreme care must be used in designing the furnace walls, so that they will stand not only the high furnace temperatures, but also the load. It is common practice at the present time to expose all of the first few rows of boiler tubes to the radiant heat from the fuel bed. This gives lower furnace temperature and greater life to the brickwork.

No arch construction or special brickwork is required in the application of underfeed stokers, and in fact it is preferable not to have arches. On account of the differences in the coefficients of expansion of different kinds of brick, however, only one kind should be used in the furnace.

Proper provision must be made for taking care of the expansion as the setting heats up. The brick should be carefully sized so that thin joints can be obtained. Each brick should be dipped in a thin fireclay wash and tapped into place with a wooden mallet until it touches the bricks next to it.

Walls should never be so constructed that they overhang or lean toward the furnace. Walls which slope outwardly from the furnace will give much longer service.

Discussion on Stokers at Fuels Session

ALEX. D. Bailey[1] submitted a written discussion in which he said that Mr. Marsh's statement that "modern steam turbines called for greater capacities from boilers" was not the whole story. Turbine development had been in a way parallel with boiler development, and along with the development of these two major pieces of equipment had been the coincident development of all plant equipment. So far as the boilers themselves were concerned, the demand for higher capacities had been occasioned by increased fuel costs and increased equipment costs, partly due to higher pressures and partly to economic conditions.

That the boiler proper had shown itself capable of taking care of these higher rates of heat absorption without materially decreasing its efficiency was evidenced by the very marked development of stokers and other coal-burning equipment during the past few years. The chain grate, which was probably one of the oldest forms of mechanical stoker known, had had to fulfill its part in this development in order to justify its existence, and the development of the forced-draft chain grate was the result.

Just as the natural-draft chain-grate stoker had made possible the use of coals which were unsuited to existing types of stokers which were consequently cheap, so the forced-draft chain grate had made available not only low-grade fuels, but also coke breeze and smaller sizes of anthracite, which had not been previously considered suitable for power production. This economic saving alone justified the improvement in chain grates.

John M. Drabelle[2] wrote that in the Central West, particularly in Iowa, there was a rather peculiar type of fuel available, namely, one low in heat value (8500 to 9000 B.t.u. per lb. as screenings) and having a high ash content (20 to 35 per cent), the ash being easily fusible. To burn this it was necessary to have an undisturbed fuel bed, a large furnace volume, and a high ignition rate. The chain-grate stoker, judging from several years of actual operating experience, was the only stoker successful in handling this type of fuel.

In judging stoker performance it was necessary to bear in mind that it was the total cost per 1000 lb. of water evaporated and not percentage efficiency that must be dealt with. The maintenance problem was a serious and important one, also the amount of operating labor required and the item of investment, the latter in turn determining fixed charges.

The ideal chain-grate stoker, Mr. Drabelle believed, would be a combined natural-draft and forced-draft stoker operating under

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[2] Mechanical engineer, Iowa Railway & Light Co., Cedar Rapids, Iowa. Mem. Am.Soc.M.E.

the normal operating conditions of the station on natural draft and over the peak load with forced draft, thereby reducing the amount of auxiliary power required to the absolute minimum, and resulting in a lower cost per 1000 lb. of water evaporated.

J. R. Fortune[3] submitted a written discussion in which he said that there ought to be some way of designating stokers other than by the terms "underfeed" and "overfeed." There was but one type of stoker that, in his opinion, could truly be described as overfed, and that was the sprinkling stoker, which was not very well known in this country but which was quite commonly used abroad. This was the only stoker in which the fuel was fed on top of the burning fire. The fuel in the stokers of the Murphy, Roney, and chain-grate types was always, in effect, underfed. In other words, there was a layer of fuel unignited close to the grate bars near the stoker hopper, and this was overlaid with fuel which was burning almost all the way to the feed opening of the stoker. The unignited fuel close to the grate bar might extend halfway down the grate.

A. H. Blackburn[4] wrote that in drawing attention to the many types of underfeed stokers Mr. Lawrence had omitted to mention the lateral-retort stoker brought out by The Under-Feed Stoker Company of America during the present year. The novel feature of this stoker was that it fed the coal in through a main retort extending from the front wall of the furnace to the bridge wall, with lateral retorts branching off the main or central retort at right angles. The front and back walls of the furnace were protected by high air-cooled tuyeres, the stokers having been designed for working continuously around 200 per cent boiler rating. The design of the stoker enabled it to be installed without a basement and under low-set boilers that might be already installed.

Walter N. Polakov[5] in a written discussion said that, quite apart from the excellence of design and construction of its mechanism, and altogether independently of its adaptability to fuel used, the success or failure of a stoker depended largely upon the mode of its use.

The Stoker Not an Automatic Device

Sometimes it was claimed that a mechanical stoker was an automatic device and that by virtue of its so-called automatic action the plant owner could "forget his power plant." A stoker, however, was automatic only in so far as it replaced a certain amount of physical exertion by the substitution of mechanical power. For this reason alone the stoker attendant was no longer interested in how he could spare himself the pain of shoveling unnecessary coal into a furnace, and unless he had other stimuli he would let the stoker feed as much coal as it could and make as little steam as it might. Again, when supplementing a mechanical stoker automatic regulating devices were introduced, they as a rule controlled only one or few detached factors, but never the operation as a whole. Worse yet, in many cases these automatic controllers operated either a little behind time or made adjustments of conditions by steps, the consequence being that losses were increased coming and going. Even with oil firing he had on record cases where automatic regulators of merit had to be discontinued and manual control introduced in order to improve the evaporating efficiency.

The foregoing was neither theory nor generalization, but a summary of facts which had come under his observation during the last twenty years.

Wm. R. Roney,[6] who in recognition of his pioneer work in stoker design and construction had been asked by Chairman Breckenridge to share the platform and open the oral discussion, spoke briefly regarding troubles encountered in stoker operation, and said it was his experience that the human element was the most important factor in the satisfactory handling of such equipment.

David Moffat Myers,[7] agreed with Mr. Roney as to the importance of the human element. He further called attention to the fact that nothing had been said in the papers regarding marine applications of stokers. Here was a wonderful field for effecting economy; less coal would be used, thus leaving more space for carrying revenue-producing cargo. He was desirous of learning the attitude of stoker manufacturers toward automatic regulation. He thought that in specifying heights of boiler settings the figures should be related to the capacity rating expected from the boilers.

Later in the discussion Mr. Myers said that during the war, in the course of an investigation of the possibilities of stokers and Scotch boilers, he had come across a stoker that had been used extensively and successfully on locomotives. Locomotive practice was similar in some respects to marine practice, both having to deal with very cramped fireboxes and very small combustion space. The stoker in question involved also the use of a screw conveyor which brought the coal from the tender to a point at the footboard of the locomotive. From that point screws inclined at about 60 deg. carried the coal up to two points on either side of the fireboard and above it, from which points it was distributed over the fire by steam jets. In case of a breakdown on board ship, it would not be necessary to discard such a stoker, because it could be fired by hand without any difficulty.

Furnace Volume Essential for Good Design

J. E. Woodwell[8] said that one of the principal essentials of stoker design was furnace volume, for in running on high ratings at peak load it cost money to replace furnace linings, brickwork, etc., and to have boilers out of commission while such repairs were being made. Accordingly, in his last central-station design, he had installed stoker capacity 15 per cent in excess of anything that had been done in the Hell Gate and other new stations, simply as a reserve against furnace repairs and so that the boilers would be in service 100 per cent of the time.

As to automatic control, he did not agree with Mr. Polakov. Manual control could never equal automatic control under proper supervision.

Theodore Maynz[9] called attention to the fact that in operating chain-grate stokers it was necessary to watch the carbon in the ash. With some coals, running with 35 to 40 per cent air would give good carbon, but with others the air would have to be raised to 60 or 70 per cent before the total loss was a minimum.

One of the most important things in operating forced-draft and natural-draft chain-grate stokers was to have uniform coal. This was difficult, for even when it was mixed in advance, by the time it got to the coal hoppers it was segregated, the coarse going through the center and down the sides while the fine coal packed about a foot from the wall to about within a foot of the center. His company had had some success in obviating this by employing tilting and split gates in order to maintain a more even fuel bed.

The rear end of the stoker should be sealed either by banking coal against the water back or by means of ashes between the lower portion of the grate and the ash pit. With a forced-draft chain-grate stoker, the dirt coming out from the front made a boiler room almost uninhabitable, especially when there was, say, only about 0.05 in. draft in the furnace. He believed with Mr. Polakov that instruments were absolutely necessary, no matter how small the plant, and that the men appreciated them.

Edwin Lundgren,[10] replying to the questions propounded by Mr. Myers, said that one reason why stokers had not been applied extensively in marine practice was that while fuel obtained in one port might burn satisfactorily, the next fuel bunkered might give a great deal of trouble.

Another difficulty was the limited space between the tubes of the boiler and the bottom of the ship, which made it necessary to install a horizontal type of stoker. The company with which he was connected had applied that type of stoker to several ships in Europe and had reported in most cases very successful operation.

As to automatic regulation, speaking as a stoker manufacturer he would say that there were so many varying factors that must be compensated for that it could not be other than unsatisfactory. It had been his personal experience that the best control was that which an intelligent fireman would give when provided with proper

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[4] Chief engineer, Under-Feed Stoker Co. of America, Worcester, Mass. Mem. Am.Soc.M.E.

[5] Consulting engineer, New York, N. Y. Mem. Am.Soc.M.E.

[6] New York, N. Y. Mem. Am.Soc.M.E.

[7] Consulting engineer, Griggs & Myers, New York, N. Y. Mem. Am.Soc.M.E.

[8] Consulting engineer, New York, N. Y. Mem. Am.Soc.M.E.

[9] Test engineer, Cleveland Elec. Illuminating Co., Cleveland, Ohio. Mem. Am.Soc.M.E.

[10] Vice-president and chief engineer, Frederick Engineering Co., Frederick Md. Assoc-Mem. Am.Soc.M.E.

instruments for his guidance and means whereby he could easily adjust the factors that varied.

Albert A. Cary[11] called attention to a previous statment he had made to the effect that when a fuel carrying combustible gaseous matter was charged upon a hot fire bed, the first thing that happened was the distilling of the gaseous matter, this gas going up into the combustion chamber and being burned there. It was only the coke or fixed carbon that remained behind that was really consumed on the grate. Therefore, if it was desired to specify the capacity of a stoker by the rate of combustion, the latter should be expressed in pounds of fixed carbon burned per square foot of grate area per hour, not in pounds of fuel. Rousting and hand manipulation of the underfeed stoker was something that needed to be done away with in order to get the best results.

Alfred B. Carhart[12] said that he was very strongly inclined toward regulation by intelligent operators as against automatic control beyond the reach of the operator. Automatic control gave an average, but only through the intelligent operator could there be obtained adjustment to varying conditions which would be in control of the actual results of the moment, instead of historical records afterward to show what mistakes had been made.

C. G. Spencer[13] called attention to the fact that the coal now supplied to the East had entirely different characteristics from the fuels for which stations in that section had been designed. There was no reason to believe that the industrial war in the coal fields was ended, and that being the case, the pressing need was for a stoker that would handle effectively a variety of coals.

H. C. Heaton,[14] discussing the stratification of coal in bunkers, said that unless bunkers were properly designed the coal would tend to pile up and stick together on the sides of the bunkers, with the result that it would avalanche and supply successively different sizes to the grate. He had seen coals that would stand almost vertically on the sides of the bunker, which of course, was impossible to overcome. He believed that the best way to handle coal out of the bunker to the grate was with a spout that would swing and spread the fuel uniformly over the grate.

Smoke Abatement

O. P. Hood,[15] at the instance of Chairman Breckenridge, spoke briefly of the chaotic situation regarding smoke abatement in the various sections of the country. Most of the smoke ordinances, he said, were largely concerned with matters of administration. There was need for a simple statement of the technical requirements —what kind of smoke could be allowed, and for how long, etc.— and such a statement was now being drafted by a committee fathered by the Fuels Division of the Society and having in its membership representatives of the Heating and Ventilating Engineers, the Stoker Manufacturers' Association, railroads and other interested bodies. The matter of administration, it was proposed, should be left to each community for settlement. Mr. Hood, it should be stated, is chairman of the committee in question.

Henry M. Burke[16] said that as the operator of a 5000-hp. industrial plant he had found that the automatic control of the entire plant was impossible from the standpoint of efficiency, as was also control by manual means where a bonus scheme of payment obtained, because in that case the firemen were anxious to do more work and took care of too many operations to operate the plant most efficiently. He had therefore worked out standards according to the loads carried by the plant and had sectionalized the control, taking up the peak loads with manual control and carrying along the regular load by the automatic control. The plan had worked satisfactorily, not only on the stoker boilers but also on the boilers fired with fuel oil.

J. B. Crane[17] said that in his opinion the best plan was to set as many boilers in a plant as possible to carry a steady load and employ automatic regulation to keep steam pressures up to the remainder. As to furnace volume, his company had started in 1916 to put in boilers with $4^1/_2$ cu. ft. per rated hp., and the results had fully warranted that action. It was known now that instead of the melting point of the brick being the factor, it was the point at which it began to compress. Consequently, if combustion chambers were designed so that the load on the hot zone would not be more than 25 lb. per sq. in., were inclined away from the grate upward, and were provided with some means for overcoming the slight tendency of the brickwork to fall into the center of the combustion chamber, he believed that no further trouble would be experienced with combustion chambers, no matter how heavy the loads that were carried on the boilers.

Jos. J. Nelis,[18] speaking of the problems of marine men, said that the sea had not attracted the technical man as yet, and until it did, he did not think there would be a very general adoption of improved machinery.

Another matter to consider was the space available. Tests recently made by the Bureau of Mines and the Shipping Board had shown that with practically one-quarter of the volume used ashore, the Scotch boiler gave over 80 per cent efficiency, so that this boiler had been adapted for marine service because it had been found to be the best boiler; but it was passing, not because it was not the best boiler, but because pressures were coming up. Stokers had been tried on the Scotch boiler, principally the underfeed types. They would not get rid of the clinkers, however, so that they had been finally abandoned.

The marine man had one thing in his favor that the shore man did not have, namely, an absolutely steady load factor. It was therefore possible to design for a marine power plant closely, and to get higher efficiency than in the case of a shore plant with fluctuating load. There was a chance now to install stokers on ships, provided a low, flat boiler to get the furnace volume became available.

Fewer Coal Sizes Suggested

Lester C. Bosler,[19] said that anthracite coal operators thought that there should be a reduction in the number of sizes. They would like to eliminate the rice and two sizes of barley now produced and combine them into a size called bird's-eye, which would mean a size through $^1/_4$ in. and over $^1/_{16}$ in., and preferably through $^1/_4$ in. and over $^1/_{32}$ in.

M. Alpern,[20] representing the Stoker Manufacturer's Association, spoke briefly of its work in correcting evils that had cropped up, in improving the design of all stokers, and in creating a wider market for such equipment.

Chairman Breckenridge said that he did not subscribe to the idea that the furnace volume was a function of the horsepower of the boiler. He believed that it was a function of two variables: the rate at which coal was burned in the furnace and the volatile content of the coal that was being burned. In other words, the amount of volatile combustible material leaving the grate was the determining factor of furnace volume.

R. Sanford Riley,[21] in reply to a question raised by Mr. Myers in regard to fusion on the surface of the underfeed stoker because of the fuel working upward to the higher-temperature zone, said that clinkers were the logical result of thoroughly burning out ash if the ash had the proper chemical elements. As to the troubles encountered from these clinkers, which were inherent in certain kinds of coal in general, in underfeed stokers he desired to avoid arches because of the reverberatory action under them, which raised the temperature and made the clinkers still more liquid, causing them to run and make more trouble. In general this led up to the utilization of the maximum amount of radiation, using radiation as the means of transferring heat from the fuel bed to the boiler. By making this transfer as direct as possible there would result a cooler fuel bed, less trouble with brickwork, higher efficiency, and less trouble with clinkers.

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[11] Consulting engineer, New York, N. Y. Mem. Am.Soc.M.E.

[12] Precision Instrument Co., Inc., New York, N. Y. Mem. Am.Soc.M.E.

[13] Mechanical engineer, McClellan & Junkersfeld, New York, N. Y. Mem. Am.Soc.M.E.

[14] Mechanical engineer, Sargent & Lundy, Chicago, Ill. Mem. Am.Soc. M.E.

[15] Chief mechanical engineer, Bureau of Mines, Washington, D. C. Mem. Am.Soc.M.E.

[16] Mechanical engineer, Mt. Hope Finishing Co., North Dighton, Mass. Mem. Am.Soc.M.E.

[17] Engineer, The George T. Ladd Co., Pittsburgh, Pa. Mem. Am.Soc.M.E.

[18] Manager Marine Department, Power Specialty Company, New York, N. Y. Mem. Am.Soc.M.E.

[19] Mechanical engineer, Madeira, Hill & Co., Philadelphia, Pa. Mem. Am.Soc.M.E.

[20] President, American Engineering Co., Philadelphia, Pa. Mem. Am. Soc.M.E.

[21] President, Sanford Riley Stoker Co., Worcester, Mass. Mem. Am. Soc.M.E.

As to automatic regulation, the difficulty heretofore had been in getting operators with intelligence enough to regulate the fire directly, that is, the various drafts and the feed of the coal. It took a little higher grade of intelligence to regulate a regulator than it did to regulate the drafts and the coal feed directly; but he believed that before long regulators would be much more generally used, which was equivalent to saying that the grade of fire-room operators was being raised.

Regarding setting heights, it was not claimed that the specifications adopted were perfect, but it was certainly a great advantage to all to have some standard established by which some of the most serious mistakes made in the past might be avoided.

W. J. Wohlenberg,[22] discussing automatic control, said that in the case of parallel operation of a number of forced-draft stoker-fired boilers, the device first to respond to the load would be one that would be actuated by a change in pressure. That device would operate a throttle valve or an electric control governing the fan used to drive air through the fuel bed. If a similar change was desired in all parts of the equipment, every device and fan would have to have similar characteristics and then the right condition would be obtained only provided the same kind of fuel bed with the same kind of fuel was under every boiler. That, it would be seen, made parallel operation automatically very difficult.

W. G. Freer[23] said that he had spent 20 years at sea and knew what had to be accomplished in order to operate stokers on shipboard. The stoker being installed in nearly all the locomotives built by his company, he believed, could be adapted for such service. It distributed the coal evenly over the fire by means of a pair of mechanically actuated firing shovels.

J. C. Percy,[24] thought that stoker manufacturers could do away with much of the trouble experienced by their customers if they would manage in some way to furnish proper instruction to the men who were to operate their equipment.

Closures

T. A. Marsh, in closing, said that the real thing in efficiency was the cheap production of steam. Sometimes it was possible by burning a cheaper coal with low efficiency to make cheaper steam. He agreed with Mr. Riley, that automatic control was coming, for he knew of a number of installations working very successfully under such regulation in the West.

Answering Mr. Maynz on the tightness of forced-draft stokers, he would say that there were types on the market today that were very tight and would not blow out. He took exception to Mr. Cary's statement that on the grate we burned fixed carbon. We did not. It rested on the grate until it was thoroughly burned; but the only thing that we could possibly burn was gas. As to Mr. Cary's question regarding caking coals, he would say that they were not suitable for chain grates, and chain-grate manufacturers were not attempting to burn them today.

H. F. Lawrence, in summing up the comments on his paper, said, referring to Mr. Polakov's discussion, that the mechanical stoker was more than a coal-feeding mechanism. In addition to putting the coal into the furnace, it had to deposit the ash into some locality from which it could be easily removed, and also furnish the air at such places and velocities and directions as to accomplish the burning of the fuel in the best manner.

As to Mr. Myers' references to the clinker on top, the under feed stoker of course formed its ash on top. It was the feeding of the coal from the retort that flooded the ash on the fuel bed. The coal, in addition to rising up, was pushed forward so that the ash was carried forward toward the grate wall with the fuel. There was a comparatively small amount of ash, and the main feature to avoid trouble of this kind was to get the secondary coal-feeding mechanism—that which controlled the issuance of the coal from the retort—in such relation to the particular fuel and the amount that it would carry the clinker on beyond the end of the retort before depositing it.

With reference to burning different coals, the underfeed stoker was built with adjustments, the principal one being this control of the coal from the retorts, which was what made it possible to burn a wide variety of coals on the underfeed stoker.

As regarded cinders, it could be said that the higher setting heights were reducing them, and that the lower air pressures and lower velocities of air which would come as designs were improved, would also reduce them.

With reference to slag on the tubes, they were reduced by the high settings. With some fuels this slag was much worse than with others, and provision should always be made in the boiler setting to get at it and remove it.

[22] Asst. professor of mechanical engineering, Sheffield Scientific School Yale University, New Haven, Conn. Mem. Am.Soc.M.E.

[23] Power engineer, American Locomotive Co., Schenectady, N. Y. Mem. Am.Soc.M.E.

[24] Mechanical superintendent, Julius Kayser & Co., Brooklyn, N. Y. Mem. Am.Soc.M.E.

Improving Power-Plant Efficiency

There are three ways of improving power-plant efficiency—maintaining the efficiency of the operating cycle, selecting the proper equipment, and improving the equipment by changes in design. Although in coal-burning plants over-all thermal efficiencies of about twenty per cent have been obtained under favorable conditions, even in the largest plants the average for a year is far below this figure. Fifteen per cent is about the best that the average large station is doing, with many plants, having ratings for twenty thousand to thirty thousand kilowatts capacity, operating at ten per cent or less. Instead of producing a kilowatt-hour on seventeen or eighteen thousand British thermal units, the average figure will be from twenty-three thousand to over thirty thousand.

There are many conditions in plant operation that tend to reduce the average over-all efficiency; some of them are controllable and others are not so readily handled. Load factor undoubtedly has an effect, but cases are on record where, in plants of considerable difference in size, the smaller plant operating at about forty per cent and a larger one at sixty per cent load factor, the smaller plant showed thirty per cent less coal consumption per unit output than the larger station. Even though these conditions may exist, taking two plants that are alike as to equipment, if both are operated with equal proficiency, the station with the highest load factor will develop the highest over-all average efficiency.

For years it has been possible to obtain an over-all boiler-and-furnace efficiency of over eighty per cent with large stoker-fired boilers without the use of economizers, yet the average in many of the large plants is down around sixty-five per cent or less. There are a few exceptions to these figures where efficiencies up to about seventy-seven per cent have been obtained without the use of economizers. The maintenance of equipment has a marked effect on over-all efficiency and is very largely under the control of the operating force.

The wide difference in average operating efficiencies of two plants under similar conditions can be attributed to operating methods and the selection of the kind and size of equipment to serve the load. When selecting equipment, it is not always possible to obtain the arrangement that will give the highest over-all efficiency, or engineers have not felt justified in doing so. All electric drives for the auxiliaries and bleeder turbines for feed-water heating will give a higher over-all economy than using steam-driven auxiliaries. The possibilities of the station going dead have deterred power-plant engineers from taking full advantage of benefits to be obtained from this arrangement. Then again there is the matter of cost. Will the installation of equipment that will reduce the coal consumption reduce the kilowatt-hour cost at the switchboard?

Present indications are that in the near future no radical improvement in efficiency may be looked for in the design of power-plant apparatus, although the substitution of a regenerative cycle for the Rankine and higher steam pressures offer possibilities that are encouraging.

While power-plant engineers are waiting for the higher economy to be obtained from new designs, the present differences between the average over-all plant efficiency and that which can be obtained with present design of apparatus offers a fruitful field for careful study and improvement. (*Power*, Dec. 12, 1922.)

Tests of a Large Type W Stirling Boiler

Particulars Regarding Extensive Tests Recently Conducted by The Detroit Edison Company, in Which Various Baffle Arrangements and Different Grades of Coal Were Used

By PAUL W. THOMPSON,[1] DETROIT, MICH.

This paper deals with extensive tests conducted during 1921 on a large Type "W" Stirling boiler at the Connors Creek power house of The Detroit Edison Company. Four different arrangements of the boiler baffling were employed and the results obtained with each are shown. Separate tests were made using four different grades of coal in order to determine which was most suitable. Several operating tests were made to obtain data on different methods of banking, the effect on the temperature of flue gas of varying the time interval between the blowing of flues, and different methods of operating boilers during the low-load period at night.

From the results of the tests with different baffle arrangements, seventeen of these large boilers have been rebaffled with a resulting improvement in boiler-plant efficiency and an increase in the degree of superheat of the steam. Additional improvement is expected as more boilers are rebaffled. From the data and results of these tests, the Babcock & Wilcox Company, working in conjunction with The Detroit Edison Company, have developed a new design of this type of boiler. Four boilers of the new design have been installed in the Marysville power house of The Detroit Edison Company, but economy results on the installation are not yet available.

SINCE the original installation of the large Type W Stirling boilers by The Detroit Edison Company in 1911, many improvements have been made and much experience has been gained in regard to bettering the overall performance of these steam-generating units. The results of the first tests conducted on this type of boiler were presented before the Society by Dr. D. S. Jacobus in 1911. Several tests have been conducted since that time with other objects in view than to obtain accurately the efficiency, but none involving the weighing of water and coal.

Several years of experience in operating these boilers had brought about many improvements, both in methods and in design of auxiliary equipment, yet it was felt that there still remained further opportunities for improving the operating performance. The determination of means for obtaining improved performance comprised the main purpose of these tests.

Eight series comprising fifty constant-rating tests were made, during which four different grades of coal were burned and four different arrangements of the boiler baffling tried out. Table 1 gives general data and dimensions of the equipment and Table 2 the names and sources of the coals, together with the quantities burned. Figs. 1, 2, 3, and 4 show respectively the four baffle arrangements: namely, the original baffle, the "A" baffle, the "B" baffle, and the "C" baffle.

Some idea of the magnitude of the test may be gained from the fact that the total coal weighed to the stokers during the entire test was 12,137 tons, and the total water fed to the boilers 101,200 tons. During the highest-rating test the coal consumption averaged 22,550 lb. per hr. A complete record was maintained of the weights of coal and water during periods between tests, including seven firing-up and burning-out periods, from which data an overall efficiency for the entire period up to and including test No. 76 was computed and found to be 77.9 per cent.

The tests were commenced April 7, 1921, and completed August 27, 1921. The full number of observations were taken until August 6 only, after which date operating tests were conducted for the purpose of determining the effects of blowing flues at various intervals of time and also to obtain data on the amount of coal required for different kinds of banks. These tests were conducted with a reduced force, taking only the most essential observations.

During the period from April 7 to August 6 the services of 57 observers working on three eight-hour shifts were required, besides those engaged in analyzing coal and ash, and others conducting special investigations and checking methods.

Facilities were provided for analyzing the flue gases at points as close as possible to the sampling points. There were two sampling groups on each side of the boiler, one at the bottom of the superheater pass and one at the damper. In addition to these points at which gas samples were taken and analyzed in Orsats, two different types of automatic flue-gas recorders were installed, one drawing samples from four points on each side at the damper and recording an analysis of an average of these samples, and another from one point on each side at the bottom of the superheater pass.

The points at which the pass temperatures were measured are shown on Figs. 1, 2, 3, and 4. All points on the west side have even numbers and those on the east side, odd numbers. Each location except 15 and 16 represents two couples: one placed in the center C, the other placed in the south half S if it is on the east side, and in the north half N if on the west side. The furnace

TABLE 1 GENERAL DATA AND DIMENSIONS OF EQUIPMENT

Boiler:

Type W Stirling, manufactured by Babcock & Wilcox Company. Total number of tubes, 1564; diameter, 3¼ in.; 9 gage. Net effective heating surface, 23,654 sq. ft. Installed and first in operation October 25, 1920.

Superheater:

Twin B. & W., U-tube. Two superheaters having 102 tubes each. Tubes 8 gage, 2 in. in diameter; developed length, 24 ft. 11⅝ in. Total heating surface, 2996 sq. ft.

Stoker:

Underfeed stoker manufactured by American Engineering Company, Philadelphia, Pa. Two 13-retort, 2-ram stokers; total width, 22 ft. 10½ in.; effective length (both stokers), 12 ft. 5 in. (ashpit not considered in giving effective length). Projected grate area, 284 sq. ft. Width of ashpit, 3 ft. 11 in. Ratio of saturated heating surface to grate area, 83.4 to 1. Drive: variable-speed d.c. motors. Clinker grinders: independent drive by d.c. motors.

Setting:

Height of mud drums above floor	15 ft. 9 in.
Height from grate to top of combustion chamber	33 ft.
Width of combustion chamber	26 ft. 2 in.
Length of combustion chamber over grate	16 ft. 4 in.
Total volume computed above grate	8705 cu. ft.

Forced-Draft Fan:

Double conoidal blower manufactured by Buffalo Forge Co. Capacity, 74,000 cu. ft. at 6.5 in. water pressure. Driven by variable-speed d.c. motors.

Stack:

Height above center of grate	323 ft. 6 in.
Inside diameter of stack at top	15 ft. 9 in.

Dampers at boiler are motor-operated.

TABLE 2 COAL DATA

(1) Name of Coal	(2) Location of Mine	(3) Tests	(4) Coal burned during tests of column (3), lb.	(5) Duration in hours of tests of column (3)	(6) Heating value of coal, B.t.u. per lb.
Shipper "A"	Harlan, Ky.	Nos. 3 to 18	6,785,888	613	—
Shipper "A"	Harlan, Ky.	Nos. 40 to 43	1,744,337	128	12,510
Shipper "A"	Harlan, Ky.	Nos. 60 to 66	2,857,053	242	—
Shipper "A"	Harlan, Ky.	Nos. 70 to 76	3,271,959	266	—
Shipper "B"	Mingo, W. Va.	Nos. 20 to 24	2,304,682	196	13,280
Shipper "C"	Kanawha, W. Va.	Nos. 18–30 to 33	1,668,998	143	12,320
Shipper "D"	Logan, W. Va.	Nos. 50 to 54	1,937,176	154	12,200

Averages for Whole Test:

Coal per hr., lb	11,780
Water per hr., lb	98,600
Per cent rating	145.6
Apparent evaporation	8.37
Equivalent evaporation	10.10
Per cent efficiency	77.9
Weighed refuse in per cent of coal burned	11.30
Computed refuse in per cent of coal burned	13.92
Loss to stack in per cent of refuse	18.8

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Contributed by the Power Division and presented at the Annual Meeting, New York, December 4 to 7, 1922, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Abridged. All papers are subject to revision.

temperature was obtained at point F at the north and south ends of the furnace by focusing an optical pyrometer on the closed end of a carborundum tube, the tube being of ordinary test-tube shape and projecting about 30 in. into the furnace. In addition to the observations taken at the points mentioned above, a recording potentiometer was used for recording the temperatures at the two dampers separately, each record being an average of five equally spaced points on either side.

In addition to the four operating draft gages regularly provided

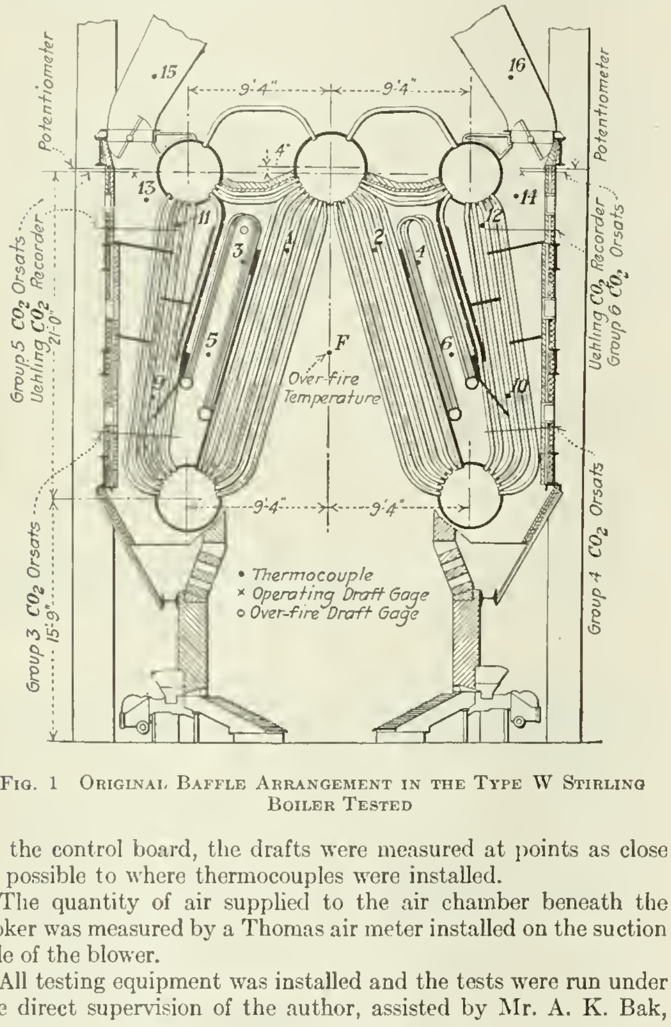

FIG. 1 ORIGINAL BAFFLE ARRANGEMENT IN THE TYPE W STIRLING BOILER TESTED

on the control board, the drafts were measured at points as close as possible to where thermocouples were installed.

The quantity of air supplied to the air chamber beneath the stoker was measured by a Thomas air meter installed on the suction side of the blower.

All testing equipment was installed and the tests were run under the direct supervision of the author, assisted by Mr. A. K. Bak, technical engineer of the Connors Creek station. Coal and water-weighing equipment was installed by the Construction Engineering Bureau of The Detroit Edison Company. The Thomas air meter and thermocouples were made and installed by the Research Department under the personal supervision of Mr. W. A. Carter. The author wishes to express his appreciation to Mr. J. W. Parker and Mr. C. F. Hirshfeld of The Detroit Edison Company, and to Dr. D. S. Jacobus of the Babcock and Wilcox Company for their valuable suggestions and criticisms, and to all those who in any way contributed to make the test a success.

TABLE 3 COMPARISON OF COAL ANALYSES

(Analyses are for dry coal and are made on duplicate samples. Samples Nos. 106, 116 and 126 are Shipper "A" coal; sample No. 138, Shipper "B" coal)

Test No.	Sample No.	Analysis made by	Proximate Analysis				Ultimate Analysis					
			Fixed carbon	Volatile matter	Ash	B.t.u.	C	H_2	O_2	N_2	S_2	Ash
4	106	D	55.30	33.50	11.20	13133[1]	73.55	4.44	8.76	1.30	0.75	11.20
		S	54.14	34.93	10.93	13297	70.57	5.15	10.93	1.38	1.04	10.93
		P	54.96	34.40	10.64	13062	73.67	4.72	8.44	1.37	1.16	10.64
9	116	D	55.15	34.55	10.30	13365[1]	74.59	4.82	7.85	1.54	0.90	10.30
		S	53.88	36.08	10.04	13284	74.91	5.13	7.83	1.14	0.98	10.04
		P	54.38	35.34	10.28	13150	74.10	4.98	8.09	1.44	1.11	10.28
14	126	D	54.90	34.85	10.25	13352[1]	75.12	4.72	7.45	1.32	1.14	10.25
		S	53.40	35.87	10.73	13298	71.94	5.30	9.26	1.44	1.33	10.73
		P	55.28	34.03	10.69	13146	72.48	4.98	9.10	1.43	1.32	10.69
24	138	D	58.75	33.50	7.75	13927[1]	75.83	5.08	9.06	1.25	1.03	7.75
		S	55.54	35.65	8.81	13520	75.88	5.90	7.01	1.26	1.14	8.81
		P	57.11	33.93	8.96	13584	77.63	5.19	5.56	1.41	1.25	8.96

[1] Values used in computations. D, The Detroit Edison Co.; S, Solvay Process Co.; P, Pittsburgh Testing Laboratory.

DESCRIPTION OF TESTS

The eight series of tests were made up of 50 constant-rating tests, each series being conducted under different conditions. The first series (tests Nos. 2 to 10) was for the purpose of obtaining the efficiency before making any changes in the boiler or its auxiliary equipment. Shipper "A" coal was used since a regular and uniform

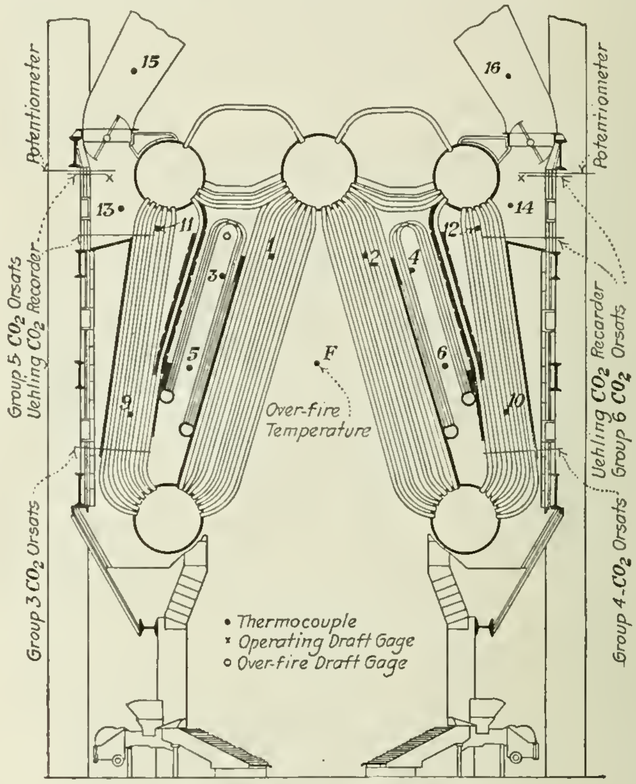

FIG. 2 "A" BAFFLE ARRANGEMENT

supply could be counted upon, and its quality was about an average of the many kinds being received at that time.

At the time the tests were commenced the boiler had been in regular service for six months, and it was decided to ascertain how much the efficiency was impaired by the soot which gradually collects on the tubes and is not removed by the soot blowers. To this end the first series of tests was conducted without specially cleaning the boiler. Then the boiler was given a thorough washing on its exterior surface and a second series of tests (Nos. 11 to 18) was run, also using Shipper "A" coal.

When Dr. Jacobus made his tests on this type of boiler in 1911 he used Red Jacket coal, so for the purpose of comparing results obtained in 1911 with those obtainable now, a series of tests was made (Nos. 20 to 24) using Shipper "B" coal, which, in quality, was as close an approximation to the coal used by Dr. Jacobus as could be obtained. This coal, however, was of poorer quality having a lower heating value and higher moisture and ash than the 1911 variety.

Tests Nos. 30 to 33 were made with Shipper "C" coal to determine its burning characteristics and adaptability for use on this type of stoker. The boiler baffling was then changed to conform to that shown in Fig. 2, called "A" baffle arrangement, and a fifth series of tests (Nos. 40

to 43) was made using Shipper "A" coal. Another series of tests using Shipper "D" coal was also made with this same baffle arrangement (tests Nos. 50 to 54) in order to obtain the burning characteristics and adaptability for use of this coal.

After test No. 54 the baffle was again changed to the "B" arrangement shown in Fig. 3, and a seventh series of tests (Nos. 60 to 66) was conducted to obtain data on the boiler operation with this baffle arrangement.

The last of the constant-rating tests (Nos. 70 to 76) were made with the boiler baffled according to arrangement "C" shown in Fig. 4, during which Shipper "A" coal was burned.

Following the constant-rating tests, additional tests were conducted to determine the effect of blowing the flues at different intervals of time upon the temperature of the gases leaving the boiler. Tests Nos. 80 to 83 were conducted for this purpose, with intervals between blowing flues as follows:

Number of test	80	81	82	83
Interval between blowing flues, hours	4	12	24	8

During these tests the boiler rating was maintained at about 155 per cent.

The following nine days the boiler was banked during the night and over Sundays to determine the amount of coal required for banking. For the first five days a so-called "dead" bank was carried and during the last four days a floating bank. During the day period the boiler was operated at approximately 157 per cent of rating. A dead bank as used here is one in which the coal feed is entirely shut off and the fire is allowed to burn back as far as possible without permitting it to go out entirely. Small amounts of coal, just sufficient to keep the fire, are fed from time to time as required. During a dead bank a boiler will cease to steam, and the pressure will fall to atmospheric if the banking period is of sufficient duration. With a floating bank the coal feed is sufficient to keep the tuyeres well covered and to hold a fire which will maintain full pressure in the boiler. With a floating bank the boiler may even continue to steam at a very low rating throughout the banking period. Each banking test was divided up into overlapping periods with a different proportion between steaming and banking hours. The coal required for banking was computed by taking the difference between the coal actually used during a period and the quantity computed as being required to evaporate the water fed to the boiler during the same period. An average heating value of the coal used during each method of banking was taken as the standard, and all coal quantities were corrected to this standard heating value.

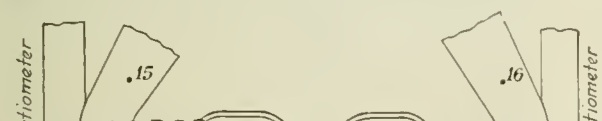

Fig. 3 "B" Baffle Arrangement

The last three tests conducted (Nos. 101–103) were strictly operating tests to determine the results of different methods of operating the boilers during the low-load period. Throughout these tests the steaming rate was varied according to the plant load, the boiler carrying its share of the total load during the day period. Test No. 101 was of 48 hr. duration with the boiler steaming at a low rate during the night. Test 102 was also of 48 hr. duration, but the boiler was subjected to a dead bank at night. Test 103 was of 25 hr. duration and the boiler was steamed at a rating of 90 per cent during the night.

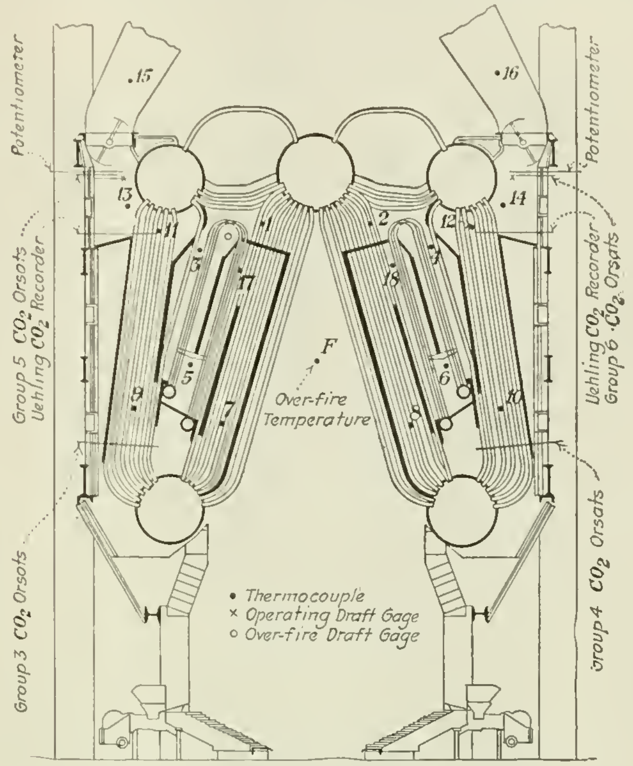

Fig. 4 "C" Baffle Arrangement

Extended tables containing the data and results obtained over all these tests are on file at the Society's headquarters and may be consulted by any one interested in their contents.

Discussion of Results

Baffle Arrangements. Figs. 5, 6, 7, 8 and 9 show the results of all the constant-rating tests in graphical form for the different baffle arrangements. Fig. 5 shows that before any changes had been made to the baffling the efficiency touched 79 per cent at 160 per cent rating. After the boiler was washed the efficiency curve was raised about 0.75 per cent, with a reduction in superheat. With the original baffling, Shipper "B" coal gave the highest efficiencies. These are shown in Fig. 6, in which are also plotted the points as reported by Dr. Jacobus in 1911 for the purpose of comparison. Fig. 8 shows the results obtained with the boiler baffled according to the "B" arrangement. These efficiencies were higher than with the original baffling, touching 83.5 per cent at 106.2 per cent rating. Due to the fact that the extension grates, which will be mentioned later, had been changed prior to this series of tests for others with larger openings, the combustible in the refuse was greater during the high-rating tests than with the original baffle. In order to correct for this loss, which is not chargeable to the baffle, a broken line has been drawn in to show what the efficiency would have been with an ashpit loss the same as during the first series of tests. With the "C" baffle arrangement the maximum efficiency reached was 82.4 per cent at 130 per cent rating. The results of this series of tests are shown in Fig. 9.

Each time the baffles were changed the row of tubes nearest the combustion chamber was partially cleaned by the workmen in making the changes, whereas the other tubes which were not touched

TABLE 4 PASS TEMPERATURES

Test No.	% Rating	Pass Temperatures. Deg. Fahr. Thermocouple Nos. 1&2	3&4	5&6	7&8	9&10	11&12	13&14	15&16	17&18	Temperature at damper, deg. fahr.	Over-fire temperature, deg. fahr.
2	116.0	1206	968	932	.....	581	547	497	....	....	547	1623
3	133.0	1274	1019	980	.....	628	576	513	....	....	587	1676
4	148.5	1320	1053	1002	....	728	589	526	......	.....	601	1708
5	163.7	1337	1071	1046	.....	671	605	547	....	......	623	1739
6	182.0	1398	1142	1109	....	722	641	576	....	......	651	1756
7	199.0	1437	1190	1152	....	760	666	597	......	....	685	1785
8A	215.0	1503	1238	1203	.....	819	705	630	......	......	719	1850
8B	210.0	1482	1222	1202	.....	830	710	621	......	....	710	1819
9	241.0	1588	1287	1257	....	860	743	651	....	....	733	1899
10	268.0	1626	1335	1304	....	914	782	651	....	......	782	2060
11B	79.0	799	721	730	....	495	476	434	436	....	473	......
12	102.8	901	773	791	.....	533	494	462	469	......	494	1260
13	53.2	685	655	664	....	474	447	432	418	......	447	.....
14	126.2	1029	848	846	....	566	509	495	486	....	504	1435
15	154.5	1149	917	928	..	612	547	533	528	......	546	1574
16	180 0	1268	1041	1026	....	680	602	591	575	.....	607	1620
17	67.4	.....	.....	.....	.....	.....	.....	.....	.....	....	469	.....
18	216.7	1373	1102	1094	....	722	638	627	608	....	645	1740
20	108.4	1024	838	852	.....	561	509	496	487	......	510	1383
21	153.3	1159	927	948	....	623	562	549	543	......	572	1534
22	193.8	1299	1034	1046	....	685	612	599	591	....	611	1652
23	224.9	1421	1146	1152	...	773	685	681	657	....	690	1778
24	145.4	1216	989	968	..	637	565	557	543	....	580	1540
30	151.4	1236	1001	977	. .	648	571	560	547	....	560	1596
31	115.0	1118	916	890	....	578	521	507	496	.....	530	.....
32	184 1	1284	1078	1055	.. .	695	601	591	572	......	619	1771
33	216.5	1428	1137	1126	....	754	647	637	616	......	655	1835
40	153.5	1190	964	972	....	736	633	580	596	......	614	1612
41	199 0	1320	1056	1076	...	827	711	659	670	....	691	1778
42	225.8	1421	1127	1154	....	905	771	716	722	......	726	1835
43	108.0	1034	876	868	.....	686	590	537	555	....	566	......
50	106.1	1077	890	888	.....	696	629	545	564	......	571	.....
51	137.0	1196	976	951	.....	738	631	575	587	....	604	1515
52	163.6	1296	1043	1029	....	799	687	631	641	....	660	1647
53	194.3	1374	1118	1089	.....	846	721	669	671	......	682	1648
54	226.4	1427	1185	1173	.....	934	793	751	747	....	751	1698
60	196.4	1338	1053	1037	746	734	648	567	623	1157	601	1703
61	168.4	1299	1022	990	712	678	607	538	580	1114	558	1671
62	142 0	1272	1050	953	676	629	568	499	538	1080	526	1669
63	106.2	1159	920	844	600	551	504	443	479	978	466	1561
64	59 0	953	781	705	535	484	455	407	428	824	407	......
65	148.5	1284	1015	962	691	635	567	503	542	1092	527	1733
66	212.5	1413	1118	1102	826	760	679	591	638	1227	620	1769
70	190 0	1339	1185	1012	680	620	663	524	571	677	547	......
71	162.0	1282	1119	949	629	576	642	487	548	641	522	......
72	134 0	1239	1086	914	607	557	627	475	528	634	499	.....
73	105.3	1111	966	821	543	516	519	423	468	588	424	......
74	149.0	1293	1128	944	636	619	603	497	539	667	507	.....
75	183.2	1393	1256	1087	698	679	653	536	577	725	558	......
76	208.5	1443	1298	1129	731	707	682	552	589	754	566	......

TABLE 5 COMPUTED PERCENTAGE OF HEATING SURFACE PASSED BY GASES

Thermocouples	Percentage of heating surface passed over by flue gases: Original baffle	"A" baffle	"B" baffle	"C" baffle
Over-fire	0	0	0	0
Nos. 1 & 2	38.8	38.8	18.8	18.2
Nos. 3 & 4	50.6	50.6	28.2	23.4
Nos. 17 & 18	.....	.....	28.2	38.8
Nos. 5 & 6	58.5	58.5	41.2	31.8
Nos. 7 & 8	.....	.....	51.2	53.3
Nos. 9 & 10	74.6	74.6	71.2	76.6
Nos. 11 & 12	95.0	95.0	95.0	95.0
Nos. 13 & 14	100.0	100.0	100.0	100.0
Nos. 15 & 16	100.0	100.0	100.0	100.0

would retain their soot deposit. When comparing "B" and "C" with the original baffling this difference in condition of heating surface should be kept in mind. The "B" baffle shows a lower stack-gas temperature and higher superheat which at its best point gives an efficiency $2^1/_2$ per cent above the efficiency obtained with the original baffling; the best point, however, being

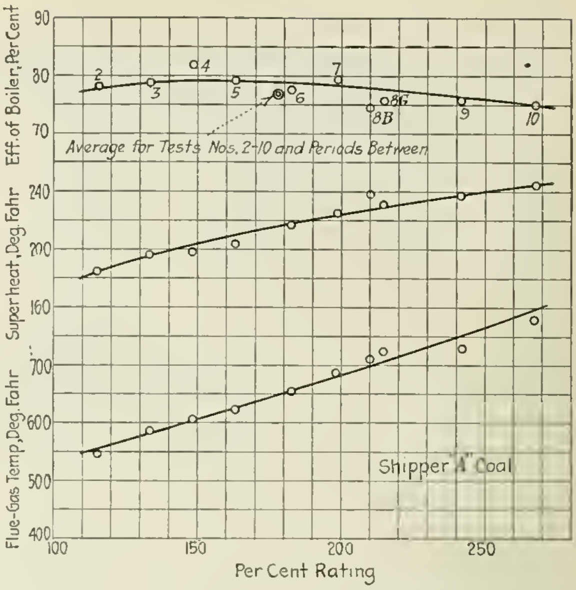

Fig. 5 Results Obtained with Original Baffle

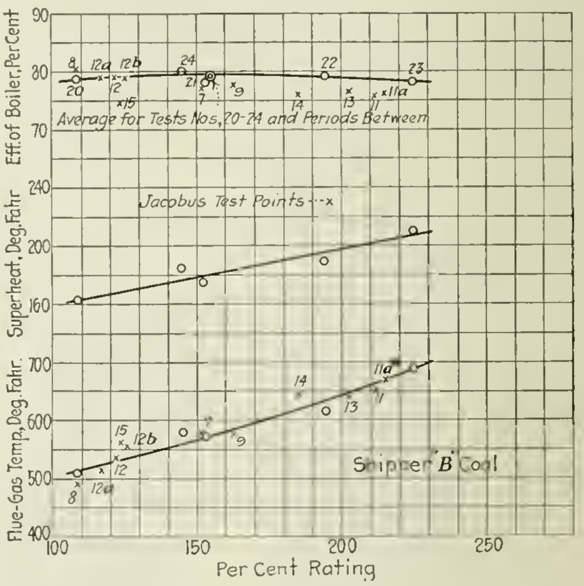

Fig. 6 Results Obtained with Original Baffle

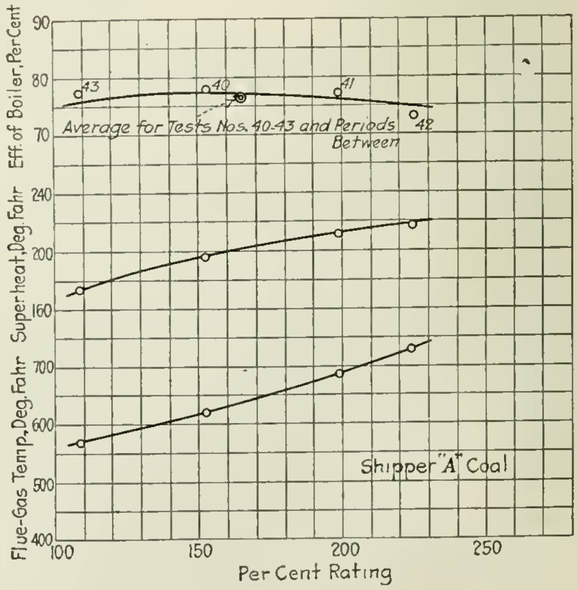

Fig. 7 Results Obtained with Baffle "A"

at a lower rating than before. Comparing the average efficiencies obtained during the entire series of tests on the original baffle before washing with the average obtained during the entire series of tests on the "B" baffle arrangement, we find that the original baffle gave 76.8 per cent at 178 per cent rating and the "B" baffle 79.1 per cent at 145 per cent rating. These results include all periods between the tests of the respective series, and one starting and burning-out period. With the original baffling after washing, the first five tests (Nos. 11–15) gave an average efficiency of 79.5 per cent at 99 per cent rating, and tests Nos. 16–18 gave 79.7 per cent at 122.8 per cent rating. From the results as shown in the

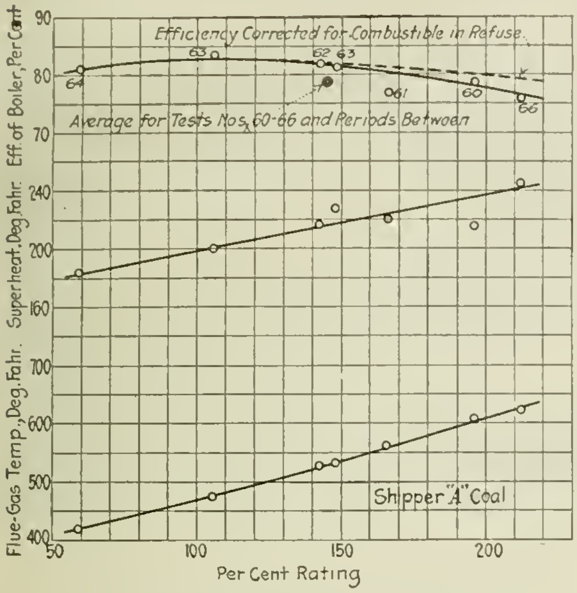

Fig. 8 Results Obtained with Baffle "B"

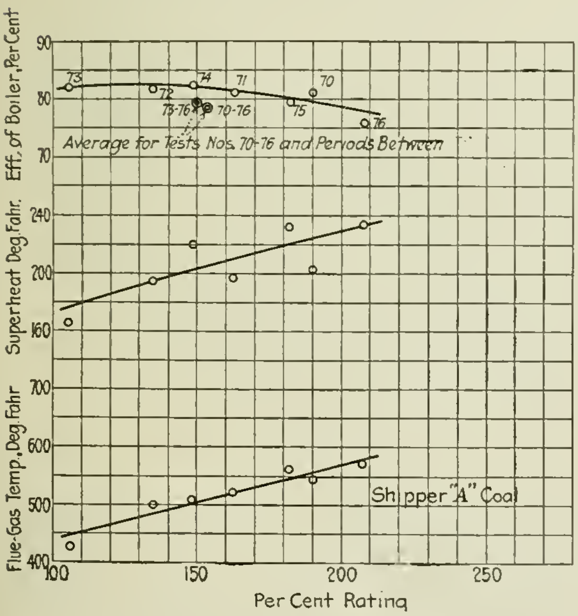

Fig. 9 Results Obtained with Baffle "C"

heat balance (Table 6), it is apparent that these efficiencies are too high.

A comparison between the average results obtained with the "B" and "C" arrangements shows the former to be 79.5 per cent at 145 per cent rating and the latter 79.8 per cent at 157 per cent rating. The gain, however, is not believed to be due entirely to the baffle arrangement, as a separation of the furnace, grate, and boiler losses show that for the "C" arrangement the unavoidable losses were 0.7 per cent lower than for the "B." Granting that a gain of 0.3 per cent in efficiency is accounted for by the "C" baffle arrangement, the fact that the "B" baffle gave a higher superheat makes it more desirable from the standpoint of overall plant economy, due to the effect of additional superheat on reducing the turbine water rate.

Extension Grates. During the tests, extension grates with different-sized openings were installed with the object of reducing the combustible in the refuse by furnishing more air over the grinders. Three different arrangements were made, including the standard grates which were in use at the beginning of the test. These original grates had a total area of openings of 11.76 sq. in. per set. At the completion of test No. 10 new grates having a total area of openings of 17.15 sq. in. were installed. Just before test No. 40 another change was made by increasing the air openings

TABLE 6 HEAT BALANCE

Test No.	% Rating	Heat absorbed by boiler	Loss due to moisture in coal	Loss due to hydrogen	Heat Lost to Stack in				Loss due to incomplete combustion	Loss due to combustible in refuse	Radiation and unaccounted for	B.t.u. in coal as fired
					Theoretical dry gas	Excess dry air	Moisture in air	Total				
2	116.0	77.9	0 3	4.5	8.9	3.0	0.2	12.1	0.5	1.9	2 8	12690
3	133.0	78.3	0.4	4.8	9.5	3.7	0 1	13.3	0.6	1.9	0.7	12650
4	148.5	81.2	0.5	3.9	9.7	3.9	0 2	13.8	0 6	2 0	-2.0	12425
5	163.7	78.9	0.5	4.5	10.1	3.2	0.2	13.5	0.4	1.8	0.4	12750
6	182.0	77.3	5.6	4 3	10.9	3.4	0.1	14.4	0.4	3 0	-0.03	12550
7	199.0	79.8	0.6	4.5	11.7	2.7	0.1	14.5	0.7	2 3	-2.4	12277
8A	215.0	75.4	0.7	4 4	12.0	3.0	0.2	15.2	0.6	3 0	0.7	12432
8B	210.0	74.4	0.5	4.4	11.8	4.1	0.2	16.1	0.7	3.0	0.9	12595
9	241.0	75.4	0.7	4 4	12.1	2.6	0 2	14.9	0.5	1.9	2.2	12550
10	268.0	75.2	0.6	4 6	13.0	2.9	0.3	16.2	1.1	1.2	1.1	12540
11B	79 0	75.8	0.5	4.1	7.2	5.1	0.3	12.6	0.5	1 8	4.7	12780
12	102 8	78.1	0.6	4.3	7.1	5.0	0.2	12.2	0.5	3.1	1 1	12563
13	53 2	76 0	0.4	4.3	7.0	6.6	0.2	13.8	0.6	2.3	2.6	12860
14	126.2	83.1	0.6	4.0	8.2	2.1	0.1	10.4	0.4	1 8	-0.3	12580
15	154.5	80 3	0.4	4.2	8.9	2.6	0.2	11.6	0.4	3.8	-0 8	12677
16	180 0	80.5	0.4	4.0	9.8	3.1	0.2	13.1	0.2	2.6	-0.8	12425
17	67.4	79.5	0.5	3.9	7.2	5.0	...	12.2	0.5	2.1	1.3	12730
18	216.7	80.5	0.3	4.0	10.6	2.8	0.2	13.6	0.3	2.9	-1.6	12690
20	108.4	79.0	0.4	4.1	8.1	4.2	0.2	12.5	0.5	2.0	1.7	13100
21	153.3	78 3	0.4	3.6	9.1	4.0	0.1	13.2	0.4	1.4	2.7	13280
22	193.8	79.9	0.4	4.7	9.6	1.8	0.1	11.5	0.5	1.7	1.2	13220
23	224.9	78.1	0.3	4.3	11.2	1.9	0.2	13.3	0.6	1.5	1.8	13330
24	145.4	80.0	0.3	4.2	7.7	4.3	0.2	12.2	0.4	1.6	1.3	13540
30	151.4	78.8	0.4	4.0	9.1	2.9	0.2	12.2	0.4	3.5	0.7	12305
31	115.0	78.6	0.3	4.2	8.4	2.6	0.2	11.2	0 2	4.0	1.5	12283
32	184.1	75.6	0.4	4.1	9.8	2.4	0.3	12.5	0.3	2.6	4.5	12300
33	216.5	77.1	0.3	3.8	10.8	2.7	0.3	13.8	0.3	4.1	0.6	12390
40	153.5	77.9	0.5	4.3	10.2	3.9	0.2	14.3	0.3	3.3	-0 6	12240
41	199 0	76.7	0.5	4.5	11.5	3.7	0.3	15.5	0.2	3.1	-0 5	12580
42	225.8	72.9	0.4	3.9	12.5	3.4	0.3	16.2	0.4	3.6	2.6	12813
43	108.0	77.3	0.5	4.2	9.3	6.2	0.2	15.7	0.5	4.1	-2.3	12357
50	106.1	77.5	0.5	4.2	9.2	6.6	0.2	16.0	0.3	4.8	-3.3	11913
51	137.0	76.0	0.5	4.3	9.8	4.4	0.2	14.4	0.2	3.6	1.0	12072
52	163.6	75.0	0.4	3.7	10.9	4.3	0.3	15.5	0.2	4.6	0.6	12380
53	194.3	76.0	0.3	4.3	10.9	2.6	0.3	13.8	0.3	4.7	0.6	12530
54	226.4	70.9	0.4	4.1	12.4	2.5	0.4	15.3	0.5	7.3	1.5	12260
60	196.4	78.5	0.5	4.1	9.8	1.6	0.3	11.7	0.4	4.3	0.5	12200
61	168.4	77.0	0.4	4.1	8.8	1.7	0.4	10.9	0.4	3.1	4.1	12445
62	142.0	81.7	0.5	4.5	8.3	1.4	0.2	9.9	0.4	2.5	0.5	12240
63	106.2	83.5	0.5	3.9	7.0	1.7	0.2	8.9	0.4	2.7	0.1	12261
64	59.0	80.9	0.3	4.2	6.1	3.3	0.2	9.6	0.1	2.8	2.1	12549
65	148.5	80.8	0.4	4.7	8.0	1.1	0.3	9.4	0.4	3.8	0.5	12220
66	212.5	75.8	0.4	3.8	10.3	1.5	0.3	12.1	0.4	5.6	1.9	12290
70	190.0	80.4	0.3	3.7	8.5	2.0	...	10.5	0.4	4.4	0.3	12730
71	162.0	81.3	0.4	3.6	7.8	2.2	0.4	10.4	0.4	3.3	0.6	12340
72	134.0	82.0	0.5	3.7	7.4	1.9	0.4	9.7	0.4	3.3	0.4	12149
23	105.3	82.2	0.3	3.6	6.3	1.8	0.2	8.3	0.3	2.6	2.7	12550
74	149.0	82.4	0.6	3.8	7.7	2.3	0.2	10.2	0.3	2.1	0.6	12118
75	183.2	79.8	0.6	3.7	8.8	2.2	0.2	11.2	0.3	2.7	1.7	12410
76	208.5	75.6	0.5	3.6	8.6	2.0	0.3	10.9	0.4	3 2	5.8	12650

through the five top bars, leaving the two bottom bars as before. The total area of openings per set was then 25.40 sq. in. The damper control was also changed and improved to give closer regulation of the air to the extension grates. This last change did not give the expected results since the combustible in the refuse increased from 3 to 5 per cent over that obtained with the original grates. Although the ash content of the coal was about 1 per cent greater than during the first series of tests, it is not believed that this could account for the increase in combustible in the refuse, since the average rating carried with the original grates was considerably higher than after the second change. The effect of the second change in extension grates should be determined from tests Nos.

60–67 and 70–76. Comparing the combustible for those tests with that obtained before and after the first change, it is seen that at low ratings the percentage after the second change was only very little greater than after the first one, although from 2 to 3 per cent greater than with the old type, and that the high averages are caused by greatly increased losses at higher ratings. That this increased loss due to combustible in refuse was due to the arrangement of air openings in the extension grates, is verified by the fact that at the completion of all tests the boiler was put back into regular plant operation, and the same difficulty with down blast through the grinders was experienced as during the test. Grates of the old type were then installed and additional observations were made at the same ratings as before, with the result that there was no down

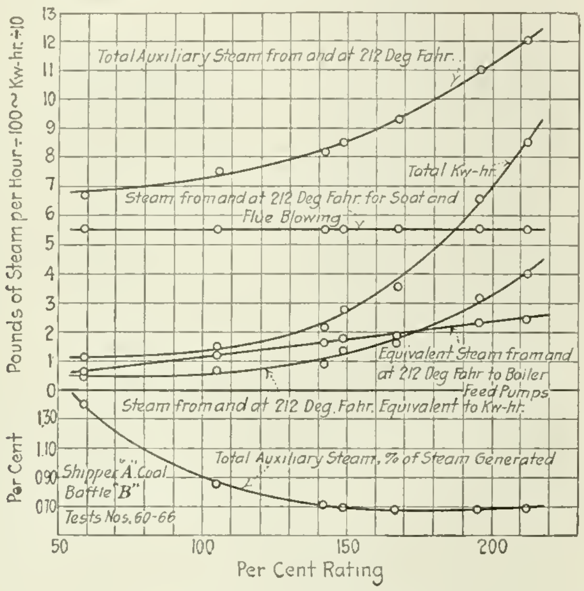

Fig. 10 Auxiliary Energy Required per Hour

blast and the refuse contained about the same percentage of combustible as during tests Nos. 2–10.

Air Supplied to Stoker. It will be seen from the results obtained from the Thomas air meter that this method of measuring the air supplied for combustion was not accurate, due to the leakage of air from the air chamber beneath the stoker. The results indicate that at high ratings the blower supplied over 25 per cent more air than was actually delivered through the stoker tuyeres. The Thomas air meter was checked against a 36-in. orifice with rounded entrance and was found to be an accurate means of measuring the quantities of air supplied by the forced-draft fan, but due to leakage from the air chamber the results could not be used for combustion computations.

Results Obtained with Different Coals. Data on the four different coals used in the tests are given in Table 2. Inasmuch as the different coals were not tested under identical conditions as regards boiler and stoker, the efficiencies obtained are not directly comparable. Except for Shipper "D" the percentage of CO_2 was about the same for the different coals, so the comparison may be made on the basis of the ashpit loss only.

Pass Temperatures. Figs. 1, 2, 3, and 4 show the points on a cross-sectional view of the boiler at which temperatures were taken, and Table 4 gives the temperatures at the different points. The readings of the thermocouples at symmetrical points in the two halves of the boiler have been averaged, and these averages are given in the table instead of the temperatures at each individual point. The over-fire temperature (point *F*) is the average of the two readings taken, one at the north and one at the south end of the combustion chamber. Points 15–16 are the average of the two readings 15 and 16, while every other point is an average of four; for instance, a point marked 3–4 is the average of thermocouples 3*S*, 3*C*, 4*N* and 4*C*. Observations obtained at point *F* are not correctly the temperature in the furnace due to the radiant heat given to the front rows of boiler tubes.

The heating surface as shown in Table 5 was computed on the basis of effective heating surface, assuming the superheater surface to have the same effectiveness in absorbing heat as the remainder of the boiler. Computations were made which showed the superheater absorbs about the same amount of heat per square foot as the average for the boiler.

Heat Losses. Table 6 gives the losses itemized in percentages of the total heat supplied in the coal. The loss due to combustible in refuse is based upon the percentage of combustible in the refuse and is computed by assuming that the refuse lost through the stack contains the same percentage of combustible as the refuse from the ashpit. Presumably the refuse to the stack contains more combustible than was shown by the analysis of the ashpit refuse, so the losses under this heading probably are slightly under the correct values.

In the radiation and unaccounted-for losses are included radiation from the boiler setting, loss due to sensible heat in refuse, loss due to unburned gases other than CO, and all errors involved in observation and analysis. Due to the fact that this item in most cases is small compared with results obtained in other tests, a few words of explanation are given to show that the radiation on this type of boiler is very low. Mr. H. Kreisinger[1] gives the radiation per square foot of exposed surface as 250 B.t.u. per hr. at 100 per cent rating and 350 B.t.u. per hr. at 200 per cent rating. The total exposed surface of this boiler, including steam drums, is 4294 sq. ft., or 1.81 sq. ft. per rated boiler hp., giving a radiation loss per hour per rated boiler hp. of 453 B.t.u. at 100 per cent rating and 634 B.t.u. at 200 per cent rating. The coal burned per rated boiler hp-hr. is practically a straight-line function between 50 per cent and 225 per cent rating, which gives 3.4 lb. per hr. at 100 per cent rating and 6.77 lb. per hr. at 200 per cent rating. This gives the radiation loss per pound of coal as 133 B.t.u. (1.06 per cent) at 100 per cent rating and 95 B.t.u. (0.76 per cent) at 200 per cent rating, assuming a coal of 12,500 B.t.u. per lb. as fired. An effort

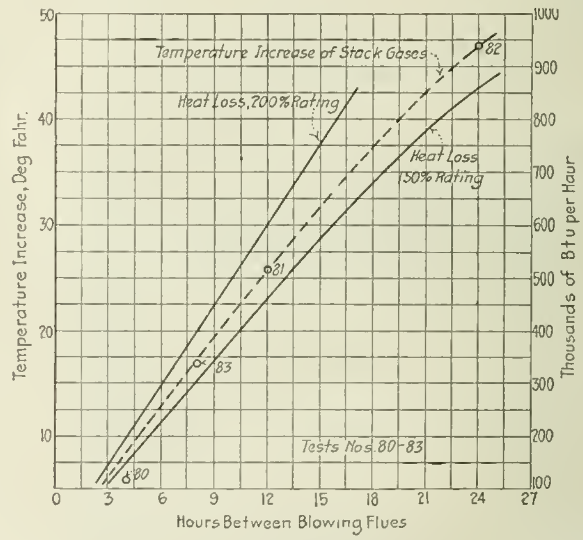

Fig. 11 Effect of Varying Time Interval between Blowing of Flues

was made to check these values by computing the radiation losses on the bases of the exposed surfaces and certain temperatures, some of which were actually measured on a boiler of this type, and some assumed. Conservative values of heat-transmission coefficients were taken, with the result that the calculation gave the radiation per pound of coal as 75 B.t.u. (0.60 per cent) at 100 per cent rating and 40 B.t.u. (0.32 per cent) at 200 per cent rating. With the exception of a few tests which were of too short duration or were otherwise unsatisfactory, the observed radiation losses did not depart from the computed radiation by more than 1.5 per cent of the heating value of the coal.

Energy Used by Boiler Auxiliaries

The stokers, blowers, and grinders were driven by direct-current variable-speed motors, the electrical input to which was measured by watthour meters. This electrical energy was all generated

[1] Boiler Tests with Pulverized Illinois Coal, H. Kreisinger and J. Blizard, Mechanical Engineering, May, 1921, p. 321.

on the auxiliary turbo-generators, the exhaust steam from which is all utilized for heating feedwater.

Fig. 10 gives for tests Nos. 60–66 the electrical energy required per hour for the blowers, stokers, and grinders, the steam equivalent to the electrical energy, and the total steam for all auxiliary uses expressed as equivalent steam from and at 212 deg. fahr.

Flue Blowing Banking—Variable-Rating Tests

Four tests (Nos. 80–83) were made to determine what effect varying the time interval between blowing flues would have on the temperature of flue gas leaving the boiler. In Fig. 11 the temperature increase has been plotted against the time interval between blowing. The B.t.u. loss per hour was computed from the mean temperature increase and is also shown in the same figure for ratings of 150 and 200 per cent.

The banking test included the period from August 13 to August 22. From August 13 to 18, the first period, dead banks were carried at night and over Sunday, and from the 18th to the 22d, the second period, floating banks were carried nights and Sunday. During the daytime the boiler was steamed at about 157 per cent rating. The results of these tests have been plotted in Fig. 12 and straight lines have been drawn through the points representing the two methods of banking. It seems probable that a straight line does not represent the true relation between the two variables, but the lack of sufficient data makes the determination of the exact relationship impossible.

These tests were conducted while the boiler was baffled according to arrangement "C." The two tests with low-rate steaming show practically the same decrease below the efficiency at constant rating (4 per cent and 3.8 per cent), whereas the test during which a dead bank was carried at night shows a decrease of 5.1 per cent.

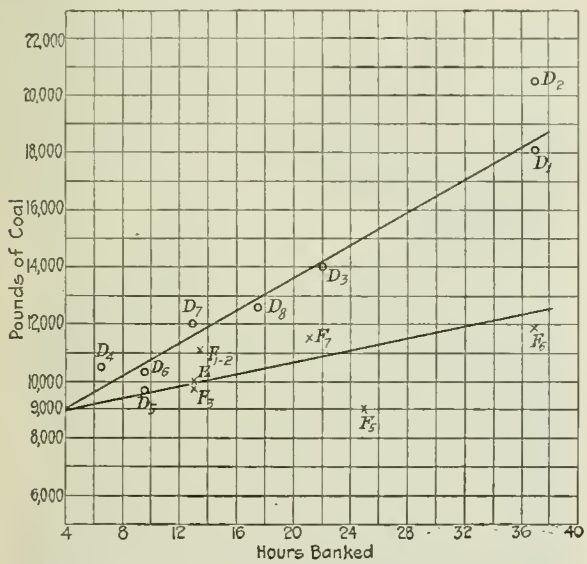

Fig. 12 Coal Required for Banking

When burning out the fires the coal was run entirely out of the spreaders and stoker hoppers, so that this amount of coal had to be added to or subtracted from the weighed coal over the starting or burning-out period. This loss and gain has been plotted against the per cent rating in Fig. 13. The ratings are those carried on the boiler at the end of the starting-up period and the beginning of the burning-out period.

Conclusions

Baffling Arrangements. The "A" baffling arrangement showed no improvement over the original arrangement except that the draft at the damper was reduced about 33 per cent.

With the "B" arrangement an average increase in superheat of over 20 deg. fahr. was obtained and the flue-gas temperature was reduced about 70 deg. fahr. as compared with the original baffling. The draft was also about 38 per cent less than with the original baffling. The results obtained indicated that there was very little difference between the "B" and "C" arrangements, and on account of the simplicity of the "B" arrangement and the fact that a slightly higher superheat was obtained, it was decided upon as the most practical arrangement to install in the present boilers.

Extension Grates. The changes made to the extension grates did not give the desired effect. After both the first and second changes the combustible present in the refuse was greater than with the old-type grates, and resulted from the trouble experienced with down blast which heated the grinders. It is believed that further

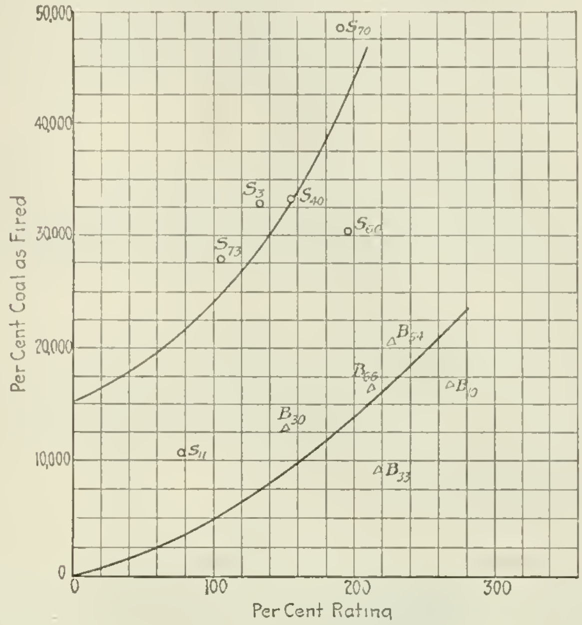

Fig. 13 Coal Lost or Gained in Starting Up and Burning Out Fires

study will develop a better arrangement of air openings, which will make possible a reduction in ashpit loss.

Air Supplied for Combustion. The method employed for measuring the air required for combustion was unsatisfactory, due to air leakage from the air chamber beneath the stoker, although the air passing through the meter was correctly indicated. This leakage amounted to as much as 25 per cent at high ratings.

Comparison of Coals. Shipper "B" coal gave only slightly better efficiency than Shipper "A" coal, while Shipper "C" coal was about 1 per cent and Shipper "D" coal 2.5 per cent lower than Shipper "A" coal. The results obtained, however, are not directly comparable due to the different arrangements of boiler baffling and conditions of the heating surface. A comparison on the basis of combustible lost in the refuse seems to be a better method. Expressed in percentage of dry coal the loss was:

Shipper	"B"	"A"	"C"	"D"
Per cent loss	1.60	2.25	3.68	4.25

Considerable difficulty was experienced with Shipper "D" coal due to the low fusion temperature of the ash, resulting in large clinkers, so that this coal was considered unsatisfactory. The other three burned satisfactorily, so that a consideration of cost f.o.b. plant, together with the relative value as fuel, determined the most economical coal. The results in this case were slightly in favor of Shipper "B."

Energy for Auxiliaries. The total energy consumed by the boiler auxiliaries averaged about 0.7 per cent between 170 per cent and 200 per cent rating, while at ratings near 50 per cent the energy consumed was 1.6 per cent. These figures are based upon the complete utilization of the exhaust steam in the feedwater heaters.

Flue Blowing. Taking into consideration the labor and maintenance costs directly influenced by the frequency of blowing flues together with the quantity of steam required per blow, an economic balance is obtained at 12.5 hr., assuming a constant rating of 200 per cent. Boilers banked at night should be blown only once a day. The foregoing is a literal interpretation of the test results which does not indicate exactly the proper procedure but serves more as a check on present practice.

Banking. Expressed in equation form, the coal required for the two methods of banking is:

Continued on page 44)

Testing Involute Spur Gears

By M. Estabrook,[1] New York, N. Y.

In this paper two new devices for testing spur gears are described: namely, the Saurer gear-testing machine, a Swiss development by means of which the accuracy of the tooth curves, spacing, and eccentricities can be determined with a high degree of precision; and the odontometer, an American instrument for quickly and accurately testing gears for tooth curves and spacing, and which can be used during the processes of manufacture, making it possible to locate troubles in the machines or tools.

In modern machine construction it has been found advantageous to pay close attention to the inspection of component parts, as in this way much time can be saved in the final assembly. Gears, however, being more intricate than most parts, have not been inspected with as much precision as other machine components.

The most commonly used method of inspecting gears is that of rolling them on centers by hand. However, it is difficult to locate the exact trouble with a pair of faulty gears in this way.

The well-known type of gear-testing machine consisting of one fixed spindle and one adjustable spindle is usually employed for testing gears on centers. This indicator will show eccentricity, faulty spacing, or large teeth.

The gear-tooth vernier is commonly used to measure the thickness of gear teeth and accurate results can be obtained with it if the vernier is kept properly calibrated. The gear-tooth micrometer, however, consisting of a straight-sided rack tooth with micrometer adjustment for depth, is superior to the gear-tooth vernier in that the contact points are planes which wear relatively slowly, and it is easier to read than the vernier.

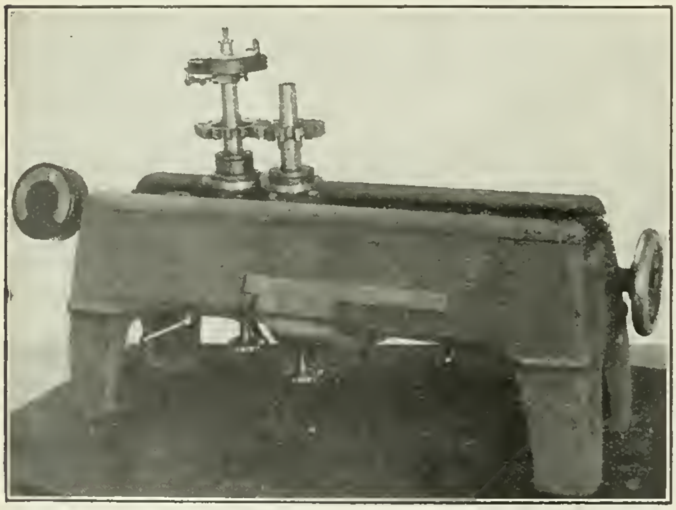

Fig. 1 The Saurer Gear-Testing Machine

An excellent method of testing large gears is to mount them on an arbor in a lathe and then arrange an indicator to bear against a plug inserted between the gear teeth.

The Kayle indicator is frequently used for testing tooth curves and consists of a straight edge arranged to roll on a disk the size of the base circle of the gear to be tested. A dial indicator shows any deviation from the true involute curve.

Projecting apparatus similar to that used for screw threads is sometimes used to examine gears, the tooth curves being compared with a correct profile.

Where large numbers of gears of a kind are to be tested, as in automobile manufacture, it is practical to devise special fixtures for testing the spacing and tooth curves of each gear. However, on account of the expense of making separate fixtures for each gear, this method is not used extensively.

The principal object of this paper, however, is to describe in detail two new devices for testing gears: the Saurer gear-testing machine, which was developed in Switzerland, and the odontometer, an instrument of American origin.

The Saurer Gear-Testing Machine

The Saurer gear-testing machine permits a more detailed study of a pair of gears than any of the devices commonly used, and with it the accuracy of the tooth curves, the spacing, and the eccentricity can be determined with a high degree of precision. The machine, shown in Figs. 1 and 2, consists of two spindles on which the gears are mounted. The spindles are also connected by two friction disks of which the diameters are the same as the pitch diameters of the gears to be tested. On one spindle there is a single sleeve which carries both the gear and its friction disk; on the other spindle there are two sleeves, one of which carries the second gear and the other the second friction disk.

When the first spindle is revolved its friction disk drives the other friction disk with a uniform velocity and its gear should drive the other gear with a uniform velocity if the gears have correct tooth curves and the spacing, etc., is accurate. In this case the two sleeves on the second spindle will revolve together. If there are inaccuracies in the gears, however, there will be a slight slippage between the sleeves. This slippage is magnified by a system of levers and a pen point traces the deviation. The magnification is about 100 to 1 for a 4-in. gear, or, expressed in another way, an angular variation of 1 min. is represented by $^1/_{16}$ in. on the chart. All of this error may be in one gear, or partly in one and partly in another. The chart shows errors in tooth curves, spacing, and eccentricity.

Fig. 2 Saurer Gear-Testing Machine, Showing Chart Being Traced

In any pair of gears there is almost always more than one kind of inaccuracy present, and, therefore, before proceeding to the examination of charts from the Saurer machine, it will be interesting to glance at Fig. 12, showing how the different kinds of errors are shown by the pen point on the chart.

A perfect gear gives a smooth circle or spiral. A spiral is produced when the friction disks are not of exactly the same diameters as the pitch diameters of the gears, but in many ways a spiral chart is preferable to a circular chart as it can be easily seen whether the

[1] Niles-Bement-Pond Co. Mem. Am.Soc.M.E.

Contributed by the Machine Shop Division and presented at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. Slightly abridged. All papers are subject to revision.

Fig. 3 Chart of Two 15-Tooth Milled Gears Showing Good Spacing but Faulty Normal Pitch and Tooth Curves

(Gears 4 pitch, $14\frac{1}{2}$ deg. pressure angle; cut with form cutter marked "15-16 teeth.")

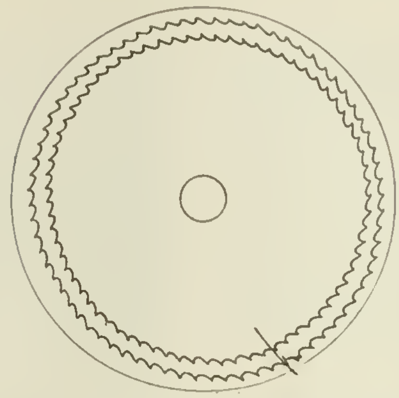

Fig. 6 Chart of a 72-Tooth Milled Gear Running with a 24-Tooth Milled Pinion, 4 Pitch. Shows Good Spacing but Faulty Tooth Curves

Fig. 9 Chart of a 72-Tooth Hobbed Gear Running with a 24-Tooth Pinion

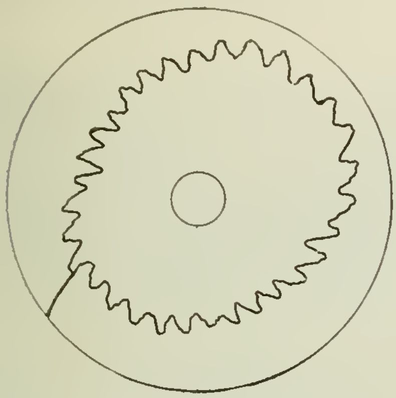

Fig. 4 Chart of 16-Tooth and 31-Tooth Automobile Gears, 6 Pitch, Showing Poor Spacing, Poor Tooth Curves, and Eccentricity

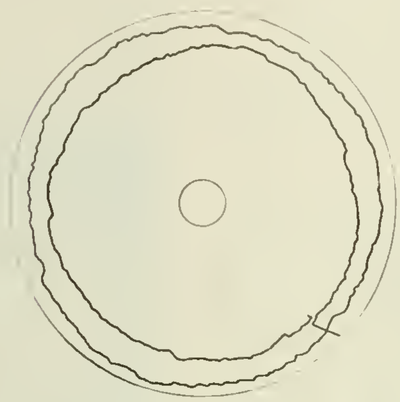

Fig. 7 Chart of a 72-Tooth Milled Gear Running with a 24-Tooth Hobbed Pinion. Shows Better Tooth Curves than Milled Pinion, but Poorer Spacing and More Eccentricity

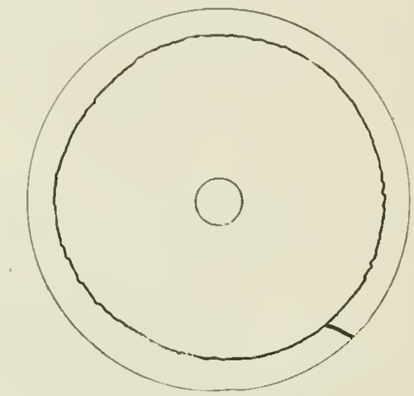

Fig. 10 Chart of a 72-Tooth Milled Gear Running with a 24-Tooth Pinion, the Teeth of the Latter Having Been Corrected to True Involute Form by Grinding

Fig. 5 Spiral Chart of Two 15-Tooth Ground Gears. Large Jump at Right Caused by a Hair Inserted between the Gear Teeth

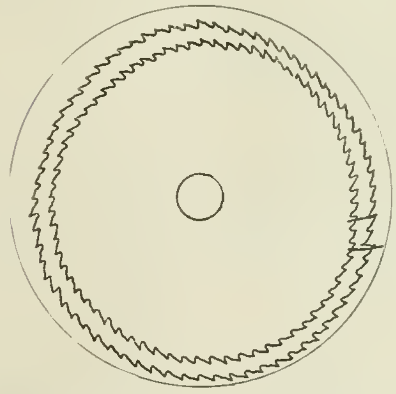

Fig. 8 Chart of a 72-Tooth Hobbed Gear Running with a 24-Tooth Milled Pinion. Shows Faulty Tooth Curves and Eccentricity

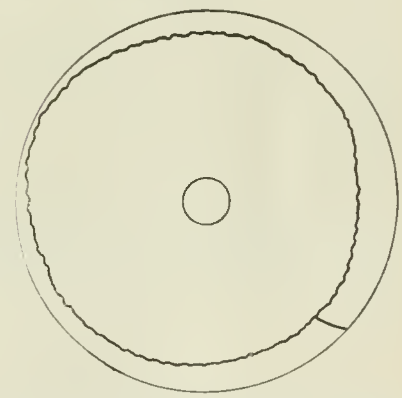

Fig. 11 Chart of a 72-Tooth Hobbed Gear Running with a 24-Tooth Pinion, the Teeth of the Latter Having Been Corrected to True Involute Form by Grinding. Chart Shows Some Eccentricity

same errors are reproduced in successive revolutions of the gears. Spacing errors are shown by quick radial jumps in the curve. Incorrect normal pitch is shown by a gradual change and then a quick radial jump. Faulty tooth curves are shown by an irregular curve for each tooth in the gear. An eccentric gear makes an eccentric chart.

The chart of Fig. 3 was made by a typical pair of 15-tooth gears, cut with a rotary cutter marked 15–16 teeth. It shows that the tooth curves are not true involutes and that they do not drive with uniform velocities at all portions of the tooth profiles. This speeding up and slowing down of the driven gear during every tooth engagement causes noise at high speeds.

The chart of Fig. 4 was made by a pair of gears for a high-grade automobile. These were procured from a service station.

Fig. 5 shows a chart made by a pair of ground gears. It is a spiral and the same errors appear in the successive parts of the spiral; the large jump was caused by a hair inserted between the gear teeth.

The charts of Figs. 6 to 11, inclusive, were made by printing-press gears cut in different ways, and show how gear action can be studied by the use of the Saurer machine. In color printing it is important to avoid streaks or gear marks on the printed page, as when these occur the wear on the plates is excessive. For this reason presses for color work require especially accurate gears. The captions under the illustrations describe the charts in detail. The two circles in the charts of Figs. 6 to 9 are made by turning one gear 180 deg. around.

These charts are a great aid in studying the action of a pair of

gears and are of material assistance in running down gear troubles. It is interesting to note that in all cases where a milled pinion is used, the charts have the characteristic sawtooth form denoting departure from the true involute tooth form. This is not so noticeable with the milled gear as the gear-tooth outline, especially when the gear has a large number of teeth, is flatter and any modification from the true involute is less apparent. The pinion is the most critical part of a gear drive and it can be seen that when the pinions are correct the charts are almost perfect.

The Saurer gear-testing machine is also provided with a vernier for setting the spindles to correct center distances and with an indicator for rapidly testing gears for eccentricity and uniformity of

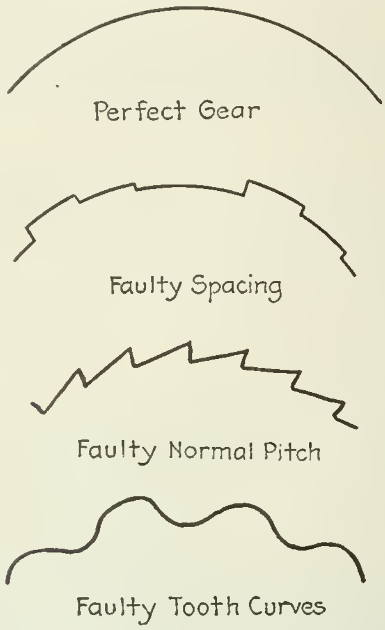

Fig. 12 Types of Charts Produced on Saurer Machine by Different Gear Inaccuracies

tooth thickness. One of the spindles is mounted on a slide that is held in position by a strong spring and is in contact with a dial indicator. When the gears are forced together this dial indicator should give a constant reading as the gears are revolved, if they are concentric.

The slide in contact with the indicator has ball bearings, making it sensitive to slight inaccuracies in the gears. It is comparatively easy to establish limits of eccentricity for any given gear when run with a master gear, and this application of the machine is useful in the commercial inspection of gears, as it is rapid, accurate, and sensitive.

The Odontometer

The odontometer was designed to meet the need for a quick, accurate gage to test gears for tooth curves and spacing. It is based on the principle that the involute curves of successive teeth are parallel—that is, the distance between the involutes measured on a normal is constant.

The instrument as shown in Fig. 13 consists of two rack teeth, one of which is fixed and the other is adjustable for different pitches. The adjustable tooth is mounted on flexible supports and is connected to a dial indicator. In use the instrument is allowed to roll in the gear to be tested. If the tooth curves are accurate involutes the needle of the dial indicator remains stationary while the two teeth of the instrument are in contact with the teeth of the gear; or, perhaps a better way of expressing it is to say that the needle pauses as the instrument is rolled in the gear. If the spacing is correct the needle pauses at the same point for each tooth. If there is no pause the tooth curves are not true involutes.

From Fig. 14 it will be seen that the odontometer does not test the whole tooth curve, but part of the dedendum of one tooth in relation to part of the addendum of the next. However, this is really the most important dimension because it is the overlap of the gears. That is, if this dimension is the same for all teeth, it means that when two teeth are driving each is taking its proportional part of the load.

To get good results from the odontometer the teeth of the gear should be smooth and should not be modified involutes. However, gears that are not true involutes can be tested for spacing errors with the odontometer.

The distance measured by the odontometer is the normal pitch, which is the same as the circular pitch on the base circle, and if the circular pitch on the pitch circle is desired, the distance measured should be divided by the cosine of the pressure angle.

In order that two gears may run together satisfactorily their normal pitches should be equal. In case there is any variation the normal pitch of the driver should never be less than the normal pitch of the driven gear.

One of the principal advantages of the odontometer is that it can be used during the process of manufacture and troubles located in the machines or tools. For instance, in grinding gears the odontometer can be used without removing the gear being tested from the machine or disturbing the setting. Further, it will measure gears designed to run at any pressure angle and can be quickly adjusted for different pitches. It can also be mounted on a stand

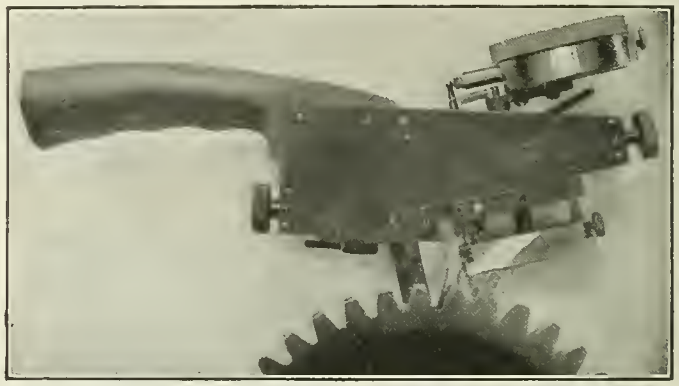

Fig. 13 Odontometer for Testing Gears of from 3 to 10 Diametral Pitch

(A smaller instrument is made for gears of 10 to 24 diametral pitch)

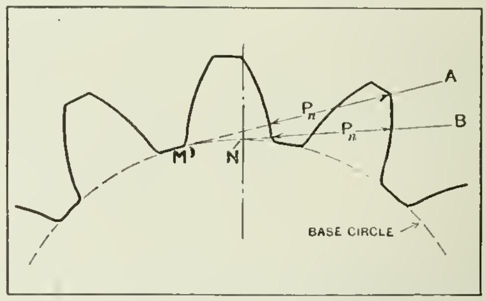

Fig. 14 Diagram Showing Part of Tooth Curve Measured by the Odontometer. Only the Part Between the Lines *AM* and *BN* is Measured

and used to measure the pinion-shaped cutters used in gear shapers.

In manufacturing, speed is of great importance and only those methods of testing gears should be selected that are relatively rapid. It should also be borne in mind that control of the equipment is fully as important as the inspection of the finished gears.

In the commercial production of precision-ground gears the Pratt and Whitney Company use the gear-tooth micrometer and the odontometer during the processes of grinding and subsequently test the finished gears by the hand-rolling or finger test and by the eccentricity test with dial indicator on the Saurer machine. The backlash and center distances are also checked on the Saurer machine and finally the gears are run under power for a noise test.

Nothing has been said regarding smoothness of tooth surface. This is an important point in the smooth running of gears, but as it is purely relative, definite limits cannot be fixed.

Attention should be called to the necessity of accurately mount-

(Continued on page 81)

Power Required for Cutting Metal

By Fred A. Parsons,[1] Milwaukee, Wis.

This paper gives results of an investigation extending over a period of more than ten years, the purpose of which has been to determine the fundamental laws governing milling, turning, planing and drilling operations on the various metals and alloys used in machine construction. In addition to a very large number of tests made on milling machines constructed by the concern with which the author is connected, those reported by Frederick W. Taylor and Professors Bird and Fairfield in the Society's Transactions have been subjected to analysis, the following variables being studied:

1 The efficiency of the machine
2 The rate of metal removal (cu. in. per min.)
3 The average thickness of chip before distortion
4 The front rake on the cutting blade
5 The material being cut
6 The spiral angle or shear on the cutting blade
7 The condition of the cutting tool, sharp or dull.

The author's results are presented in the shape of formulas and tables by means of which the power required to machine metal in any given case may be calculated, and an example of their use is worked out in detail.

In an article published in the technical press in 1920 were given the results of a preliminary study of a large number of milling tests run on Kempsmith milling machines. In the course of this study certain new laws were discovered, and a slide rule based upon them and constructed at that time gave very good results over the range of data then available. Later investigation over a wider range of tests showed, however, that further consideration was necessary, and it is the purpose here to give the results that have been obtained up to the present time.

The variables which may affect the relative power required at the drive pulley of a machine tool are, according to present data, limited to the following, there being no evidence that speed of cutting affects power economy to any marked degree:

a The efficiency of the machine
b The rate of metal removed (cu. in. per min.)
c The average thickness of chip before distortion (A.T.C.)
d The front rake on the cutting blade
e The material being cut
f The spiral angle or shear on the cutting blade (trifling)
g The condition of the cutting tool, sharp or dull.

It also seems likely that lubrication or flooding of the cutter may affect the power economy, but at present data on this point are not available.

In reality the seven variables mentioned above involve a variety of other factors, whose effect on the power required, however, is measured by their influence in fixing the value of the variables. These factors will be discussed in their proper place, as modifiers of the variables.

The data available were those of a very large number of tests made at the plant of the Kempsmith Manufacturing Company on various milling machines of their manufacture, and of other tests on power consumed, notably those of Taylor as given in his On the Art of Cutting Metals, and those of Professors Bird and Fairfield at the Worcester Polytechnic Institute (Trans. Am.Soc.M.E., vol. 26), these being chosen because the results were listed as "pressure on tool" or as "torque," from which the power to the tool itself could be computed and thus a distinction be made between the power required for cutting and that required for running the machine. The Kempsmith tests were mainly run under the following conditions:

a The machines were driven by a 25-hp. Crocker-Wheeler motor through a lineshaft having three roller bearings. This gave two belts and three roller bearings between the motor and the machine pulley
b The power input for each cut was measured by means of a voltmeter and ammeter connected through resistance across the line at the starting switch of the motor
c A reading was taken just before each test (1) of the motor, lineshaft, and machine pulley idle, and (2) of the same plus the machine with its speed and feed trains running but idle.
d The speed of the drive shaft of the machine was taken just before reading the instruments during the cut. This was done so that corrections could be made in the feed rate, from which the cubic inches of metal removed per minute was figured
e The readings for the power were taken after the cut was well under way, to make sure that the machine would really pull the cut. The No. 4 Maximiller originally incorporateda safety slip device in the feed train which caused considerable annoyance by reason of the fact that it worked too well, limiting the cut to the nominal rating of the machine, which was far under the actual limit of strength of the drive gearing or the capacity of the belt.

Some exceptions to the above conditions will be noted in their proper place.

Effect of Machine Efficiency

The efficiency of a machine is a variable quantity at different loadings. The power required to run the machine idle and the maximum efficiency of the mechanism at full load may be considered as determinants.

If a milling machine, for instance, is set up for a certain cut requiring, say, 1 hp. delivered to the pulley, and the width of the cut should then be increased fifteen times, the horsepower required at the drive pulley will not be increased in the same proportion. This is due to the increased efficiency of the machine at the new and larger load.

It was recognized that in order to arrive at consistent results the variations due to machine efficiency must be eliminated. Fig. 1 shows the efficiency at various loadings for two machines, one having 90 per cent maximum efficiency and the other 70 per cent. This chart was plotted as follows:

a The zero point in the efficiency curve was taken as 0.6 hp. from the average results of a number of tests of the power required to run the No. 4 Kempsmith Maximiller with all gearing running but idle
b The high points in the hp.-output lines were determined by a series of tests, which, while not very satisfactory, nevertheless showed that for a milling machine with anti-friction bearings a maximum efficiency of at least 90 per cent may be expected if the design is good, while for a machine having plain bearings throughout it may drop to as low as 70 per cent
c Taking these efficiencies as the extremes for milling machines of the two types gave the two lines for hp. output, and from the readings of these lines at intermediate points the values for plotting the efficiency curve were determined.

Referring to the first case mentioned, the 1 hp. delivered to the pulley would represent, according to Fig. 1, about $^1/_3$ hp. output from the machine, that is, to the cutter, on the 90 per cent machine. It is this value which must be increased fifteen times or to 5 hp. Again, reading from Fig. 1, this would require an input of 6 hp. or six instead of fifteen times the power for the first cut. The results on the 70 per cent machine would of course be somewhat different.

This all shows very conclusively that cutting tests must be corrected for horsepower and for machine efficiency before consistent results can be expected. The method used in doing this in these tests was to reduce all horsepower values to a value of "hp. delivered to the cutter" or tool hp. This can then be used to obtain a value of "cubic inches of metal removed per horsepower delivered to cutter," from which curves may be plotted for varying conditions.

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[1] Chief Engineer, Kempsmith Milling Machine Co. Mem. Am.Soc.M.E.

Contributed by the Machine Shop Division and presented at the Annual Meeting New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. Abridged. All papers are subject to revision.

Effect of Rate of Metal Removal

The horsepower varies directly as the cubic inches of metal removed per minute, but only if all the other factors remain constant. This would seem fairly obvious, but it has been very much obscured by the variations caused by other factors, especially the variation in machine efficiency at various loadings and the variation in proportionate chip pressure for different thicknesses of chip.

Effect of Varying the Average Thickness of Chip (A.T.C.)

In the earlier investigation it was discovered that the power required for milling was closely related to the feed per tooth per revolution and to the depth of cut, the two items being considered separately. Later it was found that these items should be combined into an expression "Average Thickness of Chip" which influenced spiral and face mills alike (in fact, lathe tools, drills, etc. as well), gave uniform results over an extreme range of tests, and made

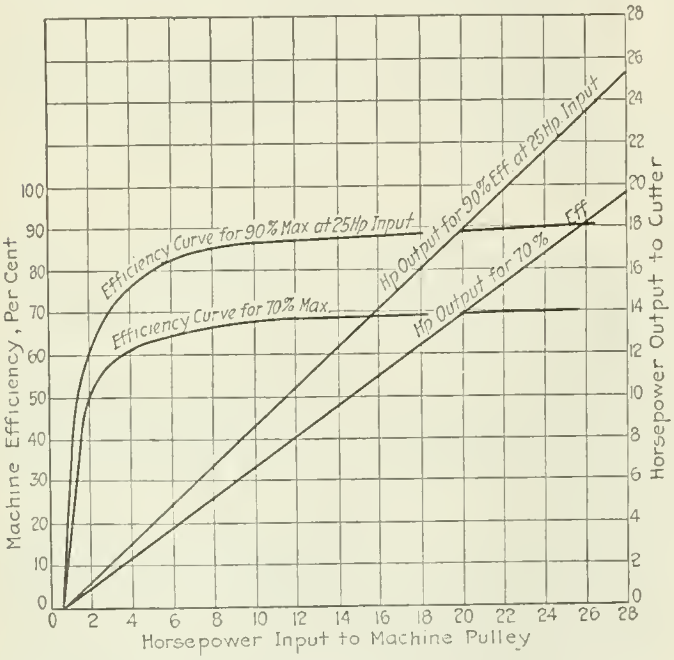

Fig. 1 Ideal Machine. Horsepower Output and Input and Efficiency at Various Loadings

proper allowance for the cutter diameter. Variations in the diameter of the cutter had been recognized during the first investigation as influencing the power required, but no definite law established which could be incorporated into the formulas.

The A.T.C. affects the power required for removal of metal directly according to a root of its value, the index of the root varying with different materials. Fig. 2 gives the results of a large number of tests and shows the relation for a variety of materials. This chart is a summary of five charts shown in the complete paper.

It will be noted that the tests charted include a considerable number for which the data were taken from the lathe tests run by Frederick W. Taylor and published by him in his book On the Art of Cutting Metals, as well as some drill tests run at the Worcester Polytechnic Institute. The fact that these tests fall into line with the milling-machine tests in such a completely satisfactory manner is considered as additional and very complete proof of the correctness of the general laws as formulated in Fig. 2. The logs of these tests are on file at the Society's headquarters and may be consulted by any one interested in their contents.

Several of the materials indicated in Fig. 2 have been tested for only a single point (see Table 1), and it is therefore not certain that the laws given for these should be considered as fully determined. From the fact that the lines for two materials, cast iron (machine castings) and soft steel, both come to a common point at about 0.0001 A.T.C., it is believed that this may safely be assumed for all other materials also. With this as a fixed point a single test is then sufficient to locate another, the two determining the direction of the line for the material tested, and thus determining the

TABLE 1 MILLING TESTS OF VARIOUS MATERIALS ON KEMPSMITH NO. 4 MAXIMILLER

Cutter: diam., 4¼ in.; no. of teeth, 14; deg. spiral, 25; deg. rake, 10; speed, 48 r.p.m. Cut: depth, 0.250 in.; width, 5¾ in.; feed per min., 6.27 in.; feed per rev., 0.13 in.; feed per tooth, 0.0093 in.; A.T.C., 0.0021 in.; cu. in. metal removed per min. 9.

Material	Test Sheet No.	Hp. to cutter	Cu. in. per hp. to cutter	Ratio of cu. in. per hp.
Cast iron (soft machine casting) through scale	4005–1	5.71	1.58	1.07
Do., no scale	4005–4	6.06	1.48	1 00
Cast iron (semi-steel 20%) through scale	4005–7	4.70	1.92	1.30
Do., no scale	4005–9	5.07	1.78	1.20
Steel casting, clean—no scale	4005–11	8.90	1.01	0.68
Steel bar (soft machine steel)	4005–12	10.30	0.88	0.60
Brass casting (yellow brass)	4005–14	4.00	2.26	1 53
Aluminum casting (commercial alloy)	4005–16	1.80	5.00	3.40

formula. The lines for aluminum and brass were thus determined. Those for steel and for machine cast iron were determined for nearly the full extent of the chart, and those for the other metals over a limited range only, but one sufficient to show that they apparently follow out the theory of a common origin for the lines of all materials.

The A.T.C. for the various types of cutting tools must be determined in various ways according to the types, which, for this purpose at least, fall into five classes as follows:

a Spiral or slabbing mills
b Formed milling cutters, as gear cutters, etc.
c Face mills (1) with square corners on blades or (2) with corners rounded or chamfered
d Lathe and planer tools
e Drills, counterbores, etc.

For spiral or slabbing mills, and in general all milling cutters with the exception of formed cutters and face mills, it can be shown that the A.T.C. depends upon the feed per tooth per revolution, the cutter diameter, and the depth of cut, the relation being expressed with sufficient accuracy for all practical purposes by a formula derived as follows:

Let D = cutter diameter
R = cutter radius
d = depth of cut
f = feed per tooth per revolution of cutter
= feed per rev. ÷ number of teeth in cutter
A.T.C = average thickness of chip
t = maximum thickness of chip.

Then, referring to Fig. 3,

$$t = 2f\sqrt{\frac{d}{D}\left(1 - \frac{d}{D}\right)}$$

whence—

$$\text{A.T.C.} = \frac{t}{2} = f\sqrt{\frac{d}{D}\left(1 - \frac{d}{D}\right)}$$

The preceding formula is based on the following analysis: Referring to Fig. 3, in the triangle with the hypotenuse R the height is obviously $R - d$, and the base, from the law of squares, equals $\sqrt{2Rd - d^2}$. Since the triangle with hypotenuse f is similar to the triangle with hypotenuse R, their similar sides are proportional, or—

$$f : t = R : \sqrt{2Rd - d^2}$$

whence—

$$tR = f\sqrt{2Rd - d^2}$$

but—

$$R = \frac{D}{2}$$

$$\therefore t = \frac{2f}{D}\sqrt{Dd - d^2} = 2f\sqrt{\frac{d}{D}\left(1 - \frac{d}{D}\right)}$$

Since the chip is a regular geometrical figure whose maximum height is t and whose ends are zero, its average height (average thickness of chip) is $\frac{1}{2}t$, or—

$$\text{A.T.C.} = f\sqrt{\frac{d}{D}\left(1 - \frac{d}{D}\right)} \quad \ldots\ldots\ldots\ldots [1]$$

Formula [1] may be still further simplified by calculating and tabulating values of $\sqrt{\frac{d}{D}\left(1 - \frac{d}{D}\right)}$ for various values of the ratio $\frac{d}{D}$, as in Table 2, thus reducing to A.T.C. = $f \times$ constant. The

greatest value of the constant being 0.5 indicates that for slabbing mills the A.T.C. cannot be greater than half the feed per tooth per revolution, this maximum value being arrived at when the depth of the cut equals half the cutter diameter.

TABLE 2 CONSTANTS FOR VARIOUS VALUES OF THE RATIO (d/D) IN FORMULA [1]

Value of Ratio $\frac{d}{D}$	Equivalent Value of $\sqrt{\frac{d}{D}\left(1-\frac{d}{D}\right)}$	Value of Ratio $\frac{d}{D}$	Equivalent Value of $\sqrt{\frac{d}{D}\left(1-\frac{d}{D}\right)}$
0.001	0.0314	0.040	0.196
0.002	0.0445	0.050	0.218
0.003	0.0556	0.060	0.238
0.004	0.0630	0.070	0.256
0.005	0.0705	0.080	0.271
0.006	0.0770	0.090	0.286
0.007	0.0832	0.100	0.300
0.008	0.0890	0.200	0.400
0.009	0.0945	0.300	0.459
0.010	0.0995	0.400	0.490
0.020	0.140	0.500	0.500
0.030	0.170	....	....

TABLE 3 CONSTANTS FOR A.T.C. FOR FORM CUTTERS
(Multiply A.T.C. obtained as for a spiral mill by the value corresponding to the ratio of d/W to obtain true A.T.C.)

Value of Ratio $\frac{d}{W}$ (See Fig. 4)	Value of W ÷ length of outline (approx.) (See Fig. 4)
0.5	0.67
1	0.45
2	0.24
3	0.16
4	0.12

against the edge of the circle generated by the revolving blades (see Fig. 5), it can be shown that the A.T.C. varies according to the ratio of the width of cut to the cutter diameter (W/D) and according to f, the feed per tooth per revolution. The A.T.C. for this type of mill is a definite ratio of W/D. (See Table 4.)

The method of arriving at the constants given in Table 4 is as follows: A face mill cutting a width W' (see Fig. 5) equal to the diameter D would have an A.T.C. equal to half the feed per tooth per

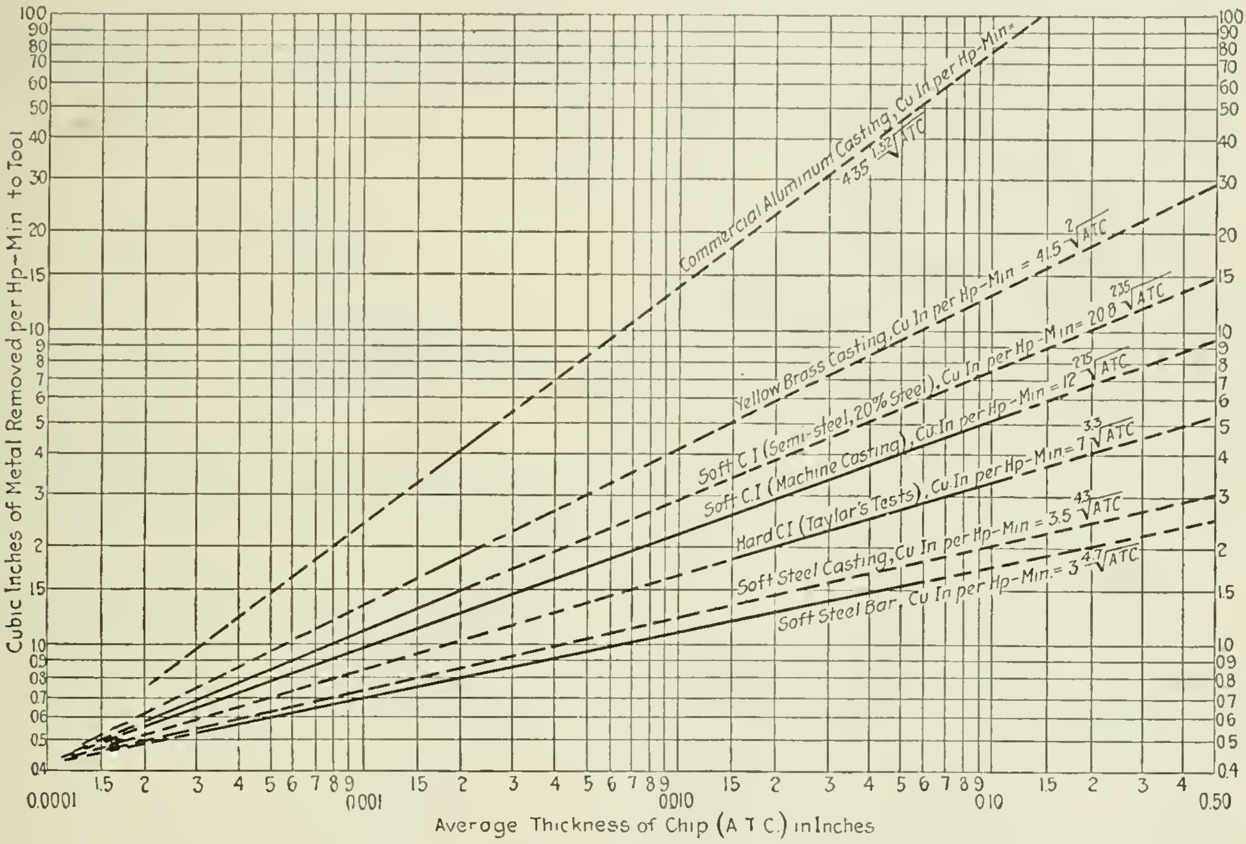

FIG. 2 RELATION OF AVERAGE THICKNESS OF CHIP (A.T.C.) TO CU. IN. PER HP-MIN. TO TOOL FOR VARIOUS MATERIALS

For formed milling cutters the A.T.C. found by the above method must be reduced in proportion to the ratio of the width of the form divided by the length around the outline (see Fig. 4); or—A.T.C.

$$\text{for form cutters} = f\sqrt{\frac{d}{D}\left(1-\frac{d}{D}\right)} \times \frac{\text{width of cut}}{\text{length around outline}}$$

This will be apparent if it is remembered that it is the *average* thickness of the chip which is required, and obviously if all the other factors remain the same an increase in the width of the chip as determined by the length of the outline will be accompanied by a corresponding decrease in the average thickness. This is explained more fully later in considering the effect of rounding on the corners of face mills.

A reasonable approximation may be had, however, if instead of employing the above method, which involves computing or measuring the outline, a constant be used representing the approximate value of W/(length of outline) for various values of d/W. Such constants are given in Table 3.

In practice the A.T.C. for form cutters should first be obtained as if for a spiral-mill cut, and then reduced as per the formula immediately preceding or by multiplying by the proper constant from Table 3.

For face mills, if the corners of the blades are square when cutting in the usual way, that is, with the work feeding centrally

TABLE 4 CONSTANTS FOR DETERMINING A.T.C.—FOR USE ONLY FOR FACE MILLS HAVING BLADES WITH SQUARE CORNERS.

Ratio $\frac{W}{D}$ (See Fig. 5)	A.T.C.	Ratio $\frac{W}{D}$ (See Fig. 5)	A.T.C.
0.1	0.999f	0.6	0.900f
0.2	0.990f	0.7	0.853f
0.3	0.976f	0.8	0.800f
0.4	0.959f	0.9	0.716f
0.5	0.932f	1.0	0.500f

revolution; for if the chip *mop* is considered as a regular geometrical outline whose greatest thickness *op* is the feed per tooth per revolution (f), and which tapers regularly to zero at the ends, it will be seen that the average thickness of such a chip will be $\frac{f+0}{2} = \frac{f}{2}$. As the width of the cut becomes smaller in proportion to the diameter D (see width W, for instance), then the A.T.C. will approach the value of f, until for a zero width of cut the ends of the chip would have the same thickness as the center and the A.T.C. would be $\frac{f+f}{2} = f$.

To determine the exact A.T.C. for intermediate widths of cuts we may use the formula as determined for spiral mills and find the value of t (see Figs. 3 and 5). Since t for a face mill is the thickness

of the end of the chip, the A.T.C. for any value of W/D will be $\frac{f+t}{2}$.

The value of t as determined for spiral mills is found by the formula $t = 2f\sqrt{\frac{d}{D}\left(1 - \frac{d}{D}\right)}$, and the same formula holds for t in Fig. 5 if d be considered as the distance from the edge of the cutter circle to the work instead of being the depth of cut as for spiral mills.

For a face mill having any width of cut W, the value of d in the

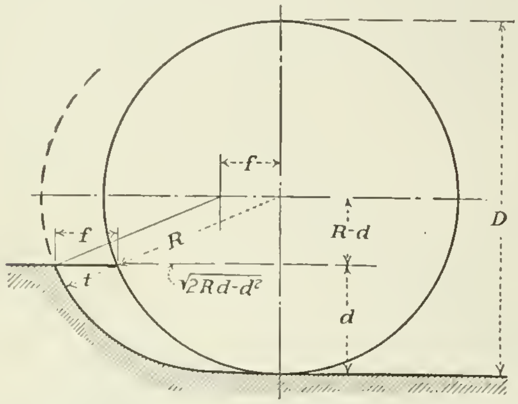

FIG. 3 THICKNESS OF CHIP FOR SPIRAL OR SLABBING TOOLS

above formula may be expressed in terms of the diameter of cutter and width of cut as follows:

$$d = \frac{D}{2} - \frac{W}{2} = \frac{D - W}{2} = 0.5(D - W)$$

Then for face mills:

$$t = 2f\sqrt{\frac{0.5(D-W)}{D}\left(1 - \frac{0.5(D-W)}{D}\right)}$$

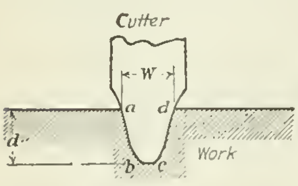

FIG. 4 REDUCTION IN A.T.C. FOR FORM CUTTERS

(W = width of form; d = depth of cut; $abcd$ = length of outline.)

It may be shown that the value of the term $0.5(D - W)$, and therefore the value of the preceding formula and also of the formula A.T.C. = $(f + t)/2$, will be constant for any given ratio of W/D if expressed in terms of f. (See list of such values in Table 4, which are much easier to use in computing A.T.C. than the formula.) The simplified formula for obtaining A.T.C. for face mills having square corners is therefore as follows, the constant being obtained from Table 4: A.T.C. = constant $\times f$.

For face mills having a corner radius on the blades, it can be shown that the A.T.C. as determined above for square-cornered mills must be decreased according to constants depending upon the ratio of the depth of cut d to the corner radius on blades r. (See list of these constants in Table 5.)

The method of arriving at these constants is as follows: If the corners of the blades are perfectly square (Fig. 6), then the width of the chip (= ek) is equal to the depth of the cut d, and the A.T.C. at all cross-sections of the cut will be the same.

If the corners are rounded (see Fig. 7), as is almost invariably the case in practice, the A.T.C. will vary at different sections of the cut, being a maximum only for sections of cut not coming on the radius of the cutter blade, as at A, and running down to zero at B. The real A.T.C. or average value of A.T.C. for all the sections would therefore depend upon the ratio of the depth of cut d to the corner radius r, or d/r. This real A.T.C. may for the moment be called A.T.C.^{R}, to distinguish from what may be called A.T.C.^{S} for a cutter with sharp corners.

TABLE 5 CONSTANTS FOR USE IN DETERMINING A.T.C. FOR FACE MILLS WITH ROUNDED CORNERS

(Multiply A.T.C. for equivalent cut with face mill having square corners by constant corresponding to value of depth of cut divided by corner radius on blades.)

Ratio $\frac{d}{R}$ (See Fig. 7)	Length of Chip = $A'B$ (See Fig. 7)	Average Area of Chip = A.T.C.$^S \times d$	Constant = $\frac{\text{area}}{\text{length}} = \frac{\text{A.T.C.}^S \times d}{A'B}$
0.1	0.445r	A.T.C.^{S} × 0.1r	0.225
0.2	0.645r	A.T.C.^{S} × 0.2r	0.31
0.4	0.925r	A.T.C.^{S} × 0.4r	0.43
0.6	1.16r	etc.	0.52
0.8	1.37r		0.58
1.0	1.57r		0.64
2	2.57r		0.78
3	3.57r		0.84
4	4.57r		0.87
5	5.57r		0.90

Now if the average area of chip is computed by multiplying the average thickness (A.T.C.^{S}) as obtained for face mills with square blade corners by the depth of cut d, this value will not be changed by the addition of the corner radius since it is obvious that if a certain area of work is removed by taking a definite number of chips, determined by speed, feed, number of teeth in cutter, etc., each chip will have a definite area regardless of its form. This can be stated thus:

$$\text{Average area} = \text{A.T.C.}^S/d$$

The addition of a corner radius, however, will change the length from gh in Fig. 5 to AB in Fig. 7, and the real average thickness or A.T.C.^{R} will therefore change accordingly, or:

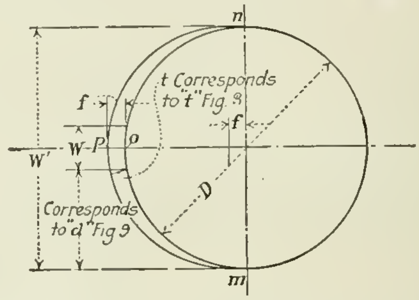

FIG. 5 DIAGRAM REPRESENTING A FACE-MILL CUT

(f = feed per tooth per rev; D = diam. of face mill; W, W' = various widths of cut; t = approx. end thickness of chip for cut of width W.)

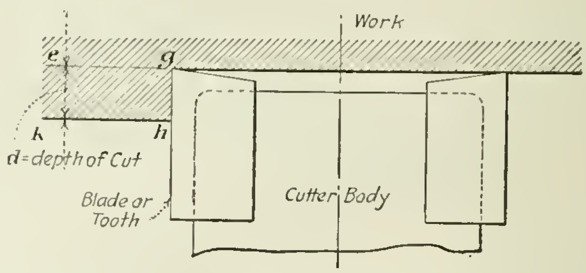

FIG. 6 FACE MILL WITH SQUARE CORNERS ON BLADES

$$\text{A.T.C.}^R = \frac{\text{average area}}{\text{length of chip}} = \frac{\text{A.T.C.}^S \times d}{\text{length}}$$

The length $A'B$ in Fig. 7 may be found by the formula—

$$\text{Length } A'B = 2\pi r \times \frac{\text{angle } S}{360°}$$

For any given value of d/r it can be shown that the length as expressed in terms of r will be constant and upon this basis it can also be shown that for any given value of d/r the value of A.T.C.^{R} will also be constant as expressed in terms of A.T.C.^{S}.

If these ratios are evaluated they result in the constants given in Table 5, by which the A.T.C. as determined for a given cut with a face mill having square corners must be multiplied to get the true A.T.C. for an equivalent cut with rounded or beveled corners.

A.T.C. FOR LATHE AND PLANER TOOLS

After having followed through the above it will be apparent that for lathe and planer tools the A.T.C. will also be dependent upon the form of the tool—

a If the tool has a sharp corner and acts square with the direction of feed, then the A.T.C. = feed per revolution or per stroke

b If the tool is rounded, or stands at an angle, the A.T.C. as determined above for the square-cornered tool must be

reduced to its true value by multiplying by the depth of cut and dividing by length of the chip, on the same principle as used in determining the true A.T.C. for face mills having rounded corners.

There are no accepted standards for tool forms in general use and therefore no table of constants can be given here, though these could easily be worked out for any standardized set of forms. For the lathe tests of Frederick W. Taylor which are incorporated in Fig. 2, the A.T.C. was modified as above according to the outlines of his standard tools as given in On the Art of Cutting Metals.

A.T.C. for Drills, Counterbores, Etc.

For counterbores, where the cutting edge is square with the feed, the A.T.C. = feed per revolution ÷ number of teeth in tool.

For drills the angle of the cutting edge must be considered. The A.T.C. as determined above should be multiplied by the cosine of the angle the cutting edge makes with the direction of the feed, which in the case of a drill ground to the standard angle of 59 deg. would be the cosine of 31 deg. or 0.857.

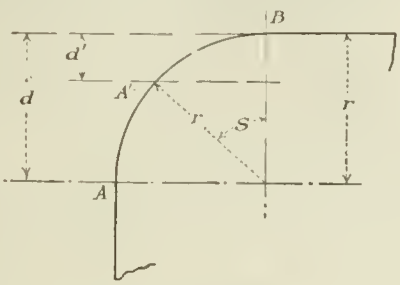

Fig. 7 Diagram of Rounded Corner of Face-Mill Blade or Tooth

(d, d' = various depths of cut; r = corner radius or equivalent bevel; $A\ B$, $A'\ B$ = length of chip.)

For the drilling tests the A.T.C. was determined as above, the cubic inches per horsepower-minute being reduced 20 per cent for the purpose of comparison with the standard line, as the line represents a tool half dulled.

Effect of the Front Rake of Cutting Blade on Power Consumed

Tests are available only for milling cutters, and only up to 12 deg. of rake (see Table 6). The results of such tests as are available seem to show that for milling cutters the power required varies directly as the ratio of the covered sine of the rake angle, or the cubic inches of metal removed per tool hp. varies inversely in the same way.

For milling cutters and lathe tools the front rake may vary considerably, and allowance according to the above should be made when computing metal removed or hp. required from the chart of Fig. 2, which is based upon milling cutters of about 10 deg. front rake and lathe tools of about 15 deg. front rake.

For drills the rake as determined by the helix angle is not subject to much variation in practice. Fig. 2 being based on drills having the rake angle of the standard twist drill (which is about equivalent to a 15-deg. average cutting rake), no allowance need be made when employing it unless the drill to be used is something other than a standard.

There is a possibility that front rake has different effects according to the material tooled, but this is not indicated to any marked extent in tests thus far available.

Power Required for Various Materials

Each material requires a different formula for determining the metal removed per hp-min. or the hp. required for any given cut—see Fig. 2.

It is apparently not possible to give any fixed ratio for the power required for different materials as this varies according to the A.T.C., the differences due to varying materials becoming small and negligible when the A.T.C. is reduced to a value of about 0.0001, as has been previously explained. The tests in Table 1 show the ratios of metal removed when the value of A.T.C. = 0.0021; ratios for other values of A.T.C. can be determined from Fig. 2.

Since allowance for various materials has already been made by the use of different lines on the chart, it is not necessary to consider this item when computing the hp. required or metal removed per hp. for any given cut, beyond choosing the proper formula or reading from the proper line.

Effect of Spiral or Helix Angle (Shear) on the Cutting Blade

It is important to distinguish between the action of a spiral angle or shear, as on a spiral milling cutter (which does not make the chip thinner), and the effect of setting a lathe tool on an angle, which thins down the chip by increasing its length while its area remains constant according to the feed in use in the same way that the chip thickness is decreased for a form cutter and for a face mill with round blade corners, as previously discussed, or by the angle on the point of a twist drill, which also thins down the chip. The effect of adding a spiral angle to a milling cutter, as far as power efficiency is concerned, seems to be largely confined to reducing the bumping action of the cut and thereby somewhat reducing the maximum power required. From the standpoint of power required this effect is not important.

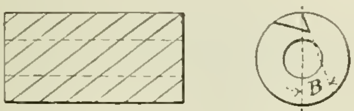

TABLE 6 EFFECT OF FRONT RAKE OF BLADES ON POWER REQUIRED FOR CUTTING METAL

Material cut, semi-steel; depth of cut, ¼ in.; width of cut, 5¾ in.; machine used, No. 4 Maximiller

Front rake B, deg.	Test Sheet No.	Cutter: Type and diam., in.	Cutter: No. of teeth	Cutter: Spiral, deg.	Speed, r.p.m	Cut: Feed per min., in.	Cut: Feed per rev., in.	Cut: Feed per tooth, in.	Cu. in. metal removed per min.	Net hp. to cutter	Cu. in. per hp-min.	A.T.C. (Average thickness of chip) in.	Cu. in. per hp-min. revised for A.T.C. = 0.002 in.	Ratio of cu. in. per hp-min.	Ratio 1/covers B
0	4004–11	Sp., 3⅛	6	26	78	4.35	0.056	0.0094	6.25	4.50	1.39	0.0025	130 } 1.35	1.00	1.00
0	4004–19	Sp., 6	10	25	35	3.55	0.103	0.0103	5.1	3.60	1.42	0.0021	140 }		
5	....	......	..	..	..	...	....	.....	....	...	...	.....	....	...	1.10
7½	4004–15	Sp., 4⅜	11	26	48	6.20	0.131	0.0119	8.9	5.40	1.65	0.0028	1.48	1.10	1.15
10	4004–9	Sp., 4¼	14	25	63	8.65	0.137	0.0098	12.4	7.60	1.64	0.0022	1.60	1.19	1.21
12	4004–13	Sp., 4⅛	11	26	63	7.35	0.117	0.0106	10.4	6.30	1.65	0.0026	1.59	1.19	1.25
15	....	......	..	..	..	...	....	.....	...	...	...	.....	....	...	1.35
20	....	......	..	..	..	...	....	.....	...	...	...	.....	....	...	1.52
25	....	......	..	..	..	...	....	.....	...	...	...	.....	....	...	1.73
30	....	......	..	..	..	...	....	.....	...	...	...	.....	....	...	2.00

A test run first with several narrow cutters set up with all the teeth on a line, and again run with the teeth staggered (to give the effect of a spiral cut), showed the power reduced in the ratio of 1.42 to 1.27 (Test sheet No. 4 Maxi. 4004–17–19).

The spiral angle is of considerable importance, however, from the fact that a large spiral angle will enable fewer teeth to be used in the spiral or slabbing cutter. The only reason for using many cutting teeth in such a cutter is in most cases to reduce the bumping action to a point where the work, jigs, and machine will stand it, and this can be done effectively with fewer cutting teeth if the spiral angle is large.

For the same reason a cutter with considerable spiral angle may take a heavier feed than one with small or no angle, though this is

often prevented by interference of chips. The increase in the feed rate is, of course, equally as effective as a decrease in the number of teeth in increasing the cutting efficiency.

No tests are available for extreme spiral angles such as those of the helical mills sometimes used, but it is believed that the greater efficiency of these mills is almost entirely due to the decreased number of teeth and consequent increase in A.T.C., which would fully account for a greatly increased efficiency.

Effect of Sharp and Dull Cutters

The condition of the cutter has a very pronounced effect on the amount of power required for removing metal. It is believed that a good part of the variations above and below the line on the various charts are due to differences in the degree of cutter sharpness.

Tests showing the variations for sharp and dull milling cutters cannot be expected to show uniform results as there is no standard for dullness. However, a number of tests (see Table 7) show that the power may be expected to increase as much as 40 per cent or more before the appearance of the cut warns the operator that it is time to resharpen in the case of milling cutters.

As the economical time between grinds varies with different jobs, being sometimes one or more days and sometimes the period required to finish a given lot of pieces, according to various considerations, it seems best to consider the entire interval from sharp to dull as ten equal units, irrespective of the time involved. The tests—1217-7, etc., Table 7—show that the cutter dulls in a fairly regular manner, and on this basis the power required could be considered as increasing regularly to a maximum of about 40 per cent above that required with a newly sharpened cutter, at which point the operator would notice that it needed resharpening from the fact that it was no longer cutting properly.

In computing power required or metal removed per tool hp. from the chart of Fig. 2, we would, according to the above method, take the results from the chart as being for a cutter which had been used for five of the allotted ten units mentioned: in other words, a cutter which was just half dulled. The computed power required for any given conditions would then be increased if the cutter had been run *more*, or decreased if the cutter had run *less*, than the time or distance required to half dull it; while if computing metal removed per tool hp. this procedure would of course be reversed, the amount of increase or decrease naturally depending upon the number of units less or more than half dulled up to approximately 20 per cent over and under for the maximum of 5 units.

The preceding paragraph refers only to milling cutters. For drills no data are available, but when allowance is made as above, they fall almost exactly on the line corresponding to the half-dulled cutter. Lathe tools, to be run economically, as shown by Taylor in his On the Art of Cutting Metals, should be run at speeds which dull them very rapidly as compared with the economical speeds for milling cutters. It is therefore probably safest to consider all lathe tools as *dull* tools, because the time interval between a sharp and a dull tool is, or should be, comparatively very short. Exceptions to this are formed tools and other tools in automatic machinery, etc., where the cost of resetting makes it necessary, as for a milling cutter, to increase greatly the time interval.

This completes the consideration of the variables mentioned at the beginning of the paper as affecting the power required for cutting metal, and from what has been set forth may be figured the power required by the cutter for almost any combination of tool and cut. Belt hp. can only be computed if the idle hp. and efficiency under some known load are known, though it can be approximated if the last item only is known, especially if the cut represents a fairly large percentage of the machine's capacity.

Example. To find the power required for a gang of 5 gear cutters of 6 pitch, No. 4, 3 7/16 diam., 13 teeth, when cutting in cast iron (semi-steel, 20 per cent steel) with a feed of 7 1/4 in. per min. and at a speed of 56.5 ft. = 63 r.p.m.

TABLE 7 POWER REQUIRED FOR DULL AND SHARP MILLING CUTTERS

Condition of Cutter	Machine	Test sheet No.	Material	Cutter: Type and diam., in.	Cutter: No. of teeth	Cutter: Spiral, deg.	Cutter: Rake, deg.	Speed, r.p.m.	Cut: Depth, in.	Cut: Width, in.	Cut: Feed per min., in.	Cut: Feed per rev., in.	Cut: Feed per tooth, in.	Cu. in. metal removed per min.	Hp to cutter	Cu. in. per hp-min. to cutter	A.T.C.	Corrected for	Cu. in. per hp-min. corrected	Ratio sharp to dull
Sharp	4P. Maxi.	2305–10	C.I.	Face mill	14	10	10	39.5	0.375	6	10.45	0.260	0.019	22.70	7.65	2.96	0.0062	none	2.96	1.45
Dull	"	2305–11	"	8½ in.	"	"	"	41.5	0.350	5	11.00	0.265	"	22.15	10.90	2.04	0.0059	"	2.04	
Sharp	"	2323–17	C.I.	Face mill	14	10	10	25.0	0.450	6	7.35	0.294	0.021	19.85	7.25	2.74	0.0069	none	2.74	1.29
Dull	"	2323–10	"		"	"	"	24.5	0.400	6	7.17	"	"	17.20	8.10	2.12	0.0066	"	2.12.	
Sharp	2P. Maxi	1217–7	Steel casts	Sp. 3¼ in.	10	25	7	88	0.187	6	4.35	0.050	0.005	4.87	5.80	0.840	0.0012	none	0.840	1.29
Has run — 76 in. = 17 min.	"	1217–11	"	"	"	"	"	"	"	"	"	"	"	·	5.95	0.820	"	"	0.820	
132 in. = 30 min.	"	1217–14	"	"	"	"	"	"	"	"	"	"	"	·	6.30	0.775	"	"	0.775	
152 in. = 34 min.	"	1217–15	"	"	"	"	"	"	"	"	"	"	"	·	6.45	0.755	"	"	0.755	
190 in. = 43 min.	"	1217–17	"	"	"	"	"	"	"	"	"	"	"	·	6.75	0.720	"	"	0.720	
228 in. = 52 min.	"	1217–19	"	"	"	"	"	"	"	"	"	"	"	·	6.81	0.713	"	"	0.713	
256 in. = 60 min.	"	1217–21	"	"	"	"	"	"	"	"	"	"	"	·	7.03	0.692	"	"	0.692	
400 in. = 90 min.	"	1218–5	"	"	"	"	"	"	"	"	4.28	"	"	4.77	7.02	0.680	"	"	0.680	
475 in. = 108 min.	"	1218–9	"	"	"	"	"	"	"	"	"	"	"	·	7.10	0.670	"	"	0.670	
650 in. = 147 min.	"	1218–18	"	"	"	"	"	"	"	"	"	"	"	·	7.25	0.660	"	"	0.660	
720 in. = 164 min.	"	1218–21	"	"	"	"	"	"	"	"	"	"	"	·	7.32	0.650	"	"	0.650	
Sharp	2P. Maxi.	1502–6	Steel bar	Face mill	18	6	1	35	0.125	6⅝	10.8	0.310	0.0173	8.95	8.58	1.030	0.0105	none	1.030	1.36
Dull	"	1502–5	"	10⅝ in.	16	6½	"	28	0.125	6⅝	11.0	0.394	0.0246	9.10	10.60	0.860	0.0140	A.T.C.	0.760	
Sharp	2P. Maxi.	1500–17	"	Face mill	16	6½	1	10	0.125	6¾	1.44	0.038	0.0024	1.22	1.51	0.810	0.0014	A.T.C.	1.43	2.00
Dull	"	1500–3	"	10 in.	"	6½	"	28	0.125	6¾	9.10	0.218	0.0136	7.51	10.70	0.700	0.0080	none	0.70	

a Find A.T.C. for equivalent speed, feed and depth for spiral mill (see Par. 28) as follows:

1 $\text{A.T.C.} = f\sqrt{\dfrac{d}{D}\left(1 - \dfrac{d}{D}\right)}$

2 f = feed per tooth per revolution = feed per rev. divided by no. of teeth in cutter = $0.115 \div 13 = 0.0088$ in.

3 For a 6-pitch gear cutter, depth $d = 0.359$ in., whence $d/D = 0.359/3\,{}^7/_{16} = 0.104$ in.

4 From Table 2 the value of $\sqrt{\dfrac{d}{D}\left(1 - \dfrac{d}{D}\right)}$ when $d/D = 0.100$ is 0.300, whence—

5 A.T.C. for equivalent spiral mill $= 0.0088 \times 0.300 = 0.0026$ in.

b The value thus obtained must be reduced to obtain true A.T.C. for the form cutter:

1 True A.T.C. for form cutters = A.T.C. for equivalent spiral-mill cut × constant representing ratio of d to W

2 Width of cut W for a 6-pitch cutter is (measured) about 7/16 in. and the standard depth is 0.359 in., whence—

$$\frac{d}{W} = \frac{0.359}{0.437} = 0.82 \text{ approx.}$$

3 From Table 3 the value of the constant for $d/W = 0.82$ is about 0.50, whence—

4 True A.T.C. = A.T.C. × constant $= 0.0026 \times 0.50 = 0.0013$ in.

c Having found the true A.T.C. as above, we may now read from Fig. 2. at the point of intersection of the line of A.T.C. = 0.0013 with the line for cast iron (semi-steel), the cu. in. per tool hp., which is 1.25 cu. in. approximately.

We would therefore expect 1.25 cu. in. of semi-steel per tool hp. for this cut if the rake on the cutter were 10 deg. and the cutter were half dulled.

d As the rake is actually 0 deg., we must make allowance therefore as per Table 6:

$$1.25 \times (1/1.21) = 1.03 \text{ cu. in. per tool hp-min.}$$

e The amount of metal removed per minute by the above cut will be 3.4 cu. in. for the 5 cutters (= feed per min. × area of cut), assuming that the area for a single cutter is one-half the depth times the circular pitch.

f Since we expect 1.03 cu. in. per hp-min., 3.4 cu. in. per min. will require $3.4/1.03 = 3.3$ hp.

g The value thus obtained is for cutters half dulled. For sharp or dull cutters this would be decreased or increased 20 per cent, respectively:

$3.3\ (1 - 0.20) = 2.65$ hp. for newly sharpened cutters
$3.3\ (1 + 0.20) = 4.12$ hp. for dull cutters.

A test cut run with conditions as noted above required 3.26 hp. to the tool with cutters which, while in good condition, had been used before and were partly dulled (No. 4 Max. Test sheet 4004–21).

h To determine the belt hp. from the tool hp., the constants for idle hp. and for efficiency under cut must be known for the machine on which the cut is to be run; this being merely the reverse of the process of finding the tool hp. Having once been determined for any given machine, the relation of output to input (see Fig. 1) for the machine can be reduced to a formula for easy use.

i On the Kempsmith No. 4 Maximiller, for instance, the 4.12 hp. for dull cutters noted in *g* above would be increased as follows:

$$(4.12 \times 1.08) + 0.6 = 5.05 \text{ belt hp. required}$$

While the foregoing method of computing the hp. required for cutting metal may be employed provided a line similar to those in Fig. 2 has been established for the material to be cut, it is much more convenient to use a slide rule in which the data have been incorporated. Such an instrument is described and illustrated in an appendix to the complete paper.

Summary

For milling machines the power economy increases—

a For both slabbing and face-milling cuts:

(1) As the r.p.m. of cutter is decreased, but only if this increases the chip thickness, as in machines having feed rate independent of spindle speed
(2) As the feed per revolution of cutter is increased
(3) As the number of teeth in cutter is decreased (but only if the r.p.m. remains constant, thus increasing the chip thickness)
(4) As the front rake is increased.

b For spiral and slabbing cutters:

(1) As the cutter diameter is decreased
(2) As the depth of cut is increased.

c For face mills:

(1) As the cutter diameter is increased
(2) As the width of cut is decreased
(3) As the corner radius or chamfer is decreased
(4) As the depth of cut is increased, but this only affects power economy when the blades have a rounded or chamfered corner.

For lathes, planers, etc., the power economy increases—

(1) As the feed per turn or per stroke is increased
(2) As the round on tool point is decreased
(3) As the angle of the tool face with direction of feed is decreased
(4) As the cutting rake is increased
(5) As the depth is increased, but this only affects power economy if the end of the tool is rounded

For drills, counterbores, etc., the power economy increases—

(1) As the feed per revolution is increased
(2) As the number of flutes or cutting edges is decreased
(3) As the spiral angle or cutting rake is increased
(4) As the drill is ground with a smaller included angle of point.

While the foregoing points the way to greater power economy, possibilities must in many cases be subordinated to practical considerations. On a miller, for instance, too slow a cutter speed, too few teeth in the cutter and too high a feed, though desirable for cutting efficiency, will cause hammering, and usually the work and jigs will not stand this, even if the machine would do so. In certain cases this can be overcome by using helical mills with large angle of teeth, but not always.

In certain other important details, also, a given set-up may fail in operation even though the computed power is well within the cutting capacity of the machine. Almost any machine may be caused to chatter, or may chatter on certain speeds and feeds, even though the cut is fully within the machine's capacity—in fact, often because the cut is too light or the cutters too sharp to put an initial strain on the supporting structure and take out the slack. More often it is due to synchronized vibrations, which are difficult to avoid for all conditions.

Of two spindle speeds, both may be equally efficient in the transmission of power and have equal belt-hp. capacity, yet the gear leverages and bearing and shaft stresses by which one is obtained may be excellent, while for the other they may be very poor, causing unsatisfactory cuts, chatter vibration, and failure.

As another instance of practical limitations (though this applies only to spiral mills) it might be supposed that more teeth in the cutter would give equal power economy with greater production per unit of time, provided the feed was increased to give the same average thickness of chip, because more chips would be cut per minute by the greater number of teeth. However, not only is there danger of chip interference, but if it be considered that the r.p.m. for a given cutter is limited for any given material, and again that the feed per revolution is limited in most cases by the finish required—which is generally accepted as being determined for spiral mills by revolutions marks and not by tooth marks—it will be seen that a point of r.p.m. and of feed per minute is soon reached where the only way left to increase the average chip thickness and obtain greater economy is to reduce the number of teeth, the only limit in this direction being, as before mentioned, the hammering action of the cutter. As the cut approaches the limit of the machine's power capacity the advantage of few teeth in the spiral mill becomes very marked in its effect upon production.

It is certainly a fact, however, in spite of these limitations, that in many cases a considerable improvement can be made by applying the foregoing laws, and the saving in power, decreased wear on machine, increase in production, etc. which are sure to result will amply repay the effort.

Fiber in Metals

The association of a fibrous structure with strong and tough materials, such as wood and rope, and the corresponding association of crystalline character with weak and brittle materials, such as sugar or bismuth, has produced in the minds of many men, and even of competent engineers, the conception that all really strong and tough materials must be fibrous, and that all crystalline substances are likely to be weak and brittle.

A study of their microstructure, however, shows that all metals in a normal condition—i.e., when not severely cold-worked—are entirely crystalline, and that the minute crystals of which they are composed show no orientation of predominant length. There is, therefore, nothing in the nature of a "fiber" in the metal itself. The individual strips or bars into which a thick bar or plate becomes more or less completely divided by the presence of "slag" bands can never be any the stronger on that account. The metal itself, in fact, possesses no real fiber; its longitudinal strength appears greater than its transverse strength only because in the transverse direction the enclosure bands make their weakening presence felt far more actually than in the longitudinal. Were they entirely eliminated, the metal would be equally strong in all directions, and yet there would be no sign of "fiber."

It would thus seem that the desire for a "fibrous" structure is in essence a mistaken one, and that the cause of the fibrous appearance is in reality a weakness and not an advantage. It is true that under certain bending tests in which the power of the metal to undergo a large amount of plastic bending constitutes the main factor, the "fibrous" material shows higher results. Here the fibrous material gains a spurious advantage from the fact that it is enabled to behave very like a bundle of bars or thin plates rather than as a single piece of material. Owing to the weakness of the slag layers, the various rods and plates are approximately free to slide over one another and a larger amount of bending occurs before fracture takes place. But this is no real gain for practical use. *The Engineer* (London), Nov. 10, 1922, pp. 499–500.

Control of Lumber-Cutting Waste and Production

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Increase in board feet per man-hour and reduction in waste percentage in the cutting department of woodworking plants by means of wage incentive are discussed in the following paper. A differential rate based upon the two factors of production and waste is paid a standard crew.

Eleven steps in the gathering of data required are described. An example of the working out of the payment method is given and its application outlined. The proper planning of cutting orders, standardization of lumber selection and drying, and operational standardization is essential to the method. An example showing results obtained is also given.

THE PURPOSE of this paper is to outline the principles and application of a wage-incentive plan which has been successfully operated to reduce waste and increase production in the cutting departments of furniture, box, toy, auto-body, and general millwork manufacturers.

Little attention has been paid to the reduction of lumber wastage in the past, and even now few concerns are giving the subject the consideration its importance warrants. When we take into account the fact that probably not over 35 per cent of the average tree is actually developed into lumber, and that of this lumber consumed in manufactured wood products from 11 to 60 per cent[2] is wasted, the necessity for conservation is evident.

The essential problem in the cutting of lumber—which differs from the cutting of metal and other materials—is the lack of constancy of the material. Two boards of the same size and supposed quality of lumber may, through the presence of knots, checks, and other defects, have to be utilized in two entirely different manners.

The usual method employed is to send orders for all current products required to the cutting room, where they are got out of the available lumber by a more or less rule-of-thumb, cut-and-try method.

After a number of years' experience in the industry, it is the author's opinion that it is absolutely impossible to utilize lumber economically in this manner; that in spite of the very variable nature of the lumber, the only solution for economical cutting is a carefully devised scientific method. The first step in the development of such a method is the collection of the following data:

1 *Production Budget.* The entire production (manufacturing budget) for a manufacturing period should be carefully estimated. This period should be never less than three months and if it is possible to estimate a year's production fairly well, it is better to make it up for this period.

2 *Parts List.* Analyze this production into a table of all parts required, grouping together all those that are interchangeable.

3 *Parts Dimensions.* Rough-dimension into length, width, and thickness the classification of parts given above.

4 *Cutting Bills.* After careful consultation with and advice from the practical management personnel, make up from this list average cutting bills for kiln loads of lumber so assorted that practically all the various usual lengths and widths may be utilized by each cutting and still satisfy the average flow of orders.

5 *Part-Stock Control.* Establish a careful physical control and perpetual-inventory method over any accumulation of part stock in order that in making up cuttings such stock may not be unduly increased over the requirements shown by the manufacturing budget.

6 *Operational Standardization.* Study and standardize each machine and manual operation in the cutting department, determining definitely the proper method, feeds, speeds, etc., and man-hour production for maximum first-quality production of the manufacturing budget.

7 *Standard Crew.* Considering the previously mentioned standards and the manufacturing budget, establish a normal working crew for the department with stated base rates of pay.

In one plant where this method was applied the original crew numbered 37 and were paid $884.80 weekly as follows:

2 supervisors	$ 59.80
22 operators	558.50
11 helpers	217.50
1 knifeman	30.00
1 sweeper	19.00
37	$884.80

The standard crew of 20 received $505 as follows:

1 foreman	$ 42.50
1 assistant foreman	32.50
1 dispatch clerk	25.00
9 operators at $26 each	234.00
6 helpers at $20 each	120.00
1 knifeman	32.00
1 sweeper	19.00
20	$505.00

8 *Board-Foot-Hours Standard.* Determine the average board footage per operative-hour required by the above-mentioned standard crew to produce the manufacturing budget.

9 *Lumber Assortment.* The general quality and sizes of lumber to be purchased should be studied to be sure that the best material for the product is available. In this connection it should be seen to that the proper thicknesses of lumber are on hand to avoid any wastage through the use of improper sizes, a common cause of waste.

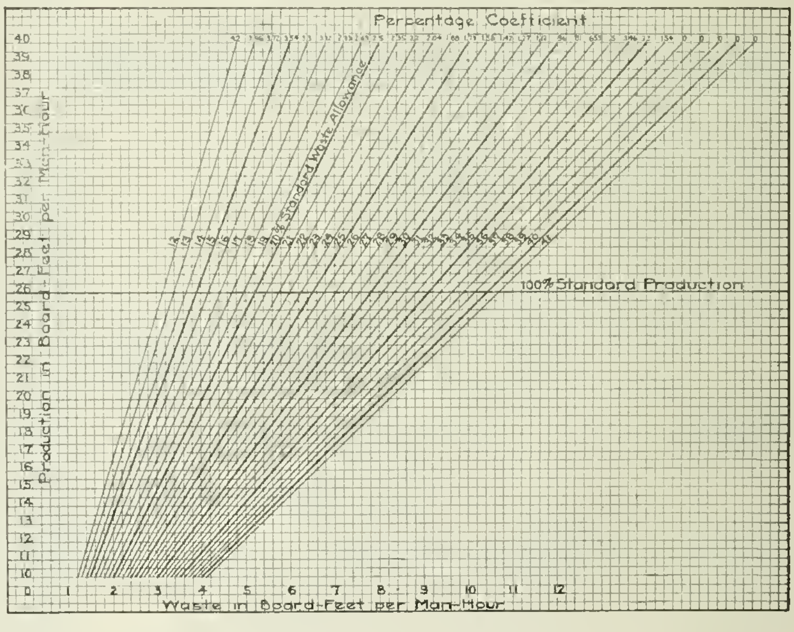

FIG. 1 PRODUCTION-WASTE RATIO CHART

(The percentage coefficient multiplied by the number of board feet produced per man-hour gives the bonus percentage for the hours worked.)

The assortment of No. 1 common, of 1s and 2s, etc., to be purchased must be based upon purely local requirements and should be proved by a series of lengthy test runs of the various grades. Such a classification developed in a certain high-grade cabinet plant was as follows:

Quartered White Oak. 1s and 2s specially selected for light color, all well-figured stock, free from mineral streaks, coarse grain, worm holes, pink flakes and sap. All stock to be well air-dried and the moisture content not to exceed 20 per cent.

Poplar. No. 1 common and selects, free from dark mineral streaks and black stain.

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[1] Chief Engineer, Cooley & Marvin Co. Mem. Am.Soc.M.E.

[2] This wide variation in wastage depends upon lumber variety and quality, product, and cutting methods.

Contributed by the Forest Products Division for presentation at the Annual Meeting, New York, December 4 to 7, 1922, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Slightly Abridged. All papers are subject to revision.

Mahogany. 1s and 2s African, all ribbony-figured stock; end-grain stock not allowed.
Chestnut. No. 1 common and better, sound wormy.
Quartered Red Gum. No. 1 common and selects.
Sap Birch. No. 1 common and selects. On 5/8-in. birch 10 per cent of 1s and 2s and 10 per cent of No. 2 common acceptable where necessary.
Crating Lumber. 1 in. by 4 in. No. 2 common and better short-leaf yellow pine D2S to 11/16-in. square-edge soft-texture stock, random 10- to 16-ft. lengths, air-dried.

10 *Drying.* The kiln equipment and methods of drying should be carefully studied and standardized. Improper drying methods often render any attempts at waste reduction in the factory abortive.

11 *Waste Limits.* By test runs, knowledge based upon experience, and direct calculation, determine fair waste limits for the various cutting schedules, using lumber of the grades selected.

Devising and Installing the Plan

With the data available from the preceding eleven steps, we now have three major requirements:

1 Devise an incentive wage-payment plan
2 Inaugurate proper planning of cutting
3 Install the payment plan.

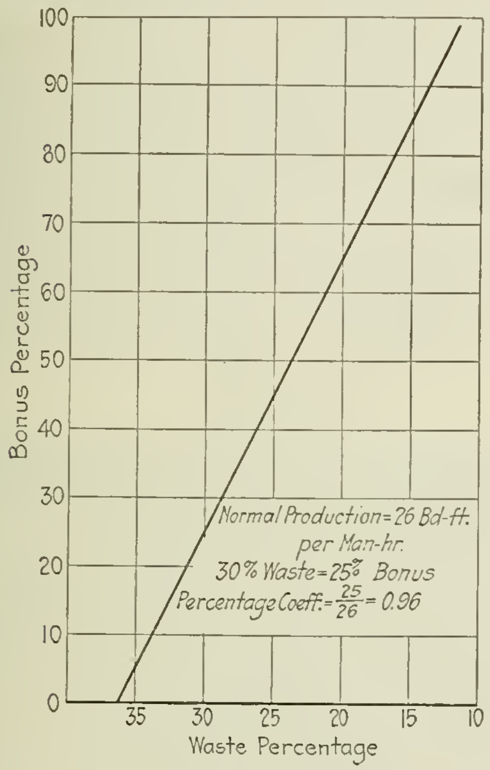

Fig. 2 Graph of Bonus Incentive for Waste Reduction at Point of Normal Production

Devising the Incentive Payment Plan. An incentive wage-payment plan for a cutting department must control both production and waste. The development of such a plan will be illustrated by an example, the plant in which it was applied being one manufacturing a very high grade of stock and special office and library furnishings and equipment.

The range of production per man-hour for the standard crew was determined to be from 11 to 30 ft. B. M., standard at 26 ft. The waste range was from 36 per cent down to 15 per cent, standard at 20 per cent.

The first step is to chart the relations between board-feet-per-hour production and waste, for a range of waste percentages somewhat wider than the standard. Such a chart is shown in Fig. 1. The percentage coefficients at the top of the chart are determined as follows:

A graph of bonus percentages for waste eliminations is plotted as shown in Fig. 2. The percentages of bonus used are determined by experience, and are set to produce the necessary incentive. The standard board footage per hour on Fig. 1 is 26. The waste bonus shown in Fig. 2 applies specifically to this production, therefore the percentage bonus allowed for any percentage of waste divided by 26 gives a coefficient which if multiplied by any board-foot production, gives an excellent differential bonus percentage for both production and waste.

For example: 30 per cent waste on Fig. 1 is allowed 25 per cent bonus; whence $25/26 = 0.96$ = coefficient for 30 per cent waste and the bonus for a production of 30 ft. B. M. hr. $= 30 \times 0.96 = 28.8$ (29) per cent; for a production of 25 ft. B. M. hr. $= 25 \times 0.96 = 24$ per cent, etc.

Fig. 4 is then calculated from the coefficients determined on Fig. 1, and gives the direct bonus percentage for each combination of waste and production within the standard range.

Inauguration of Planning of Cutting. A complete list of active dimension sizes, arranged according to woods, thicknesses, lengths, widths, and net board footage of each block, with adjacent columns showing clear sides and edges required, color requirements and, in the case of quartered oak, quartering-figure requirements, should be used by the planning department, and the superintendent and foreman of the lumber-cutting department in their coördinated efforts to put through economical dimension schedules of each kiln load of lumber ordered in.

The use of the standard cutting lists to make up a dimension-cutting schedule is as follows:

In the layout of the production orders in the planning department

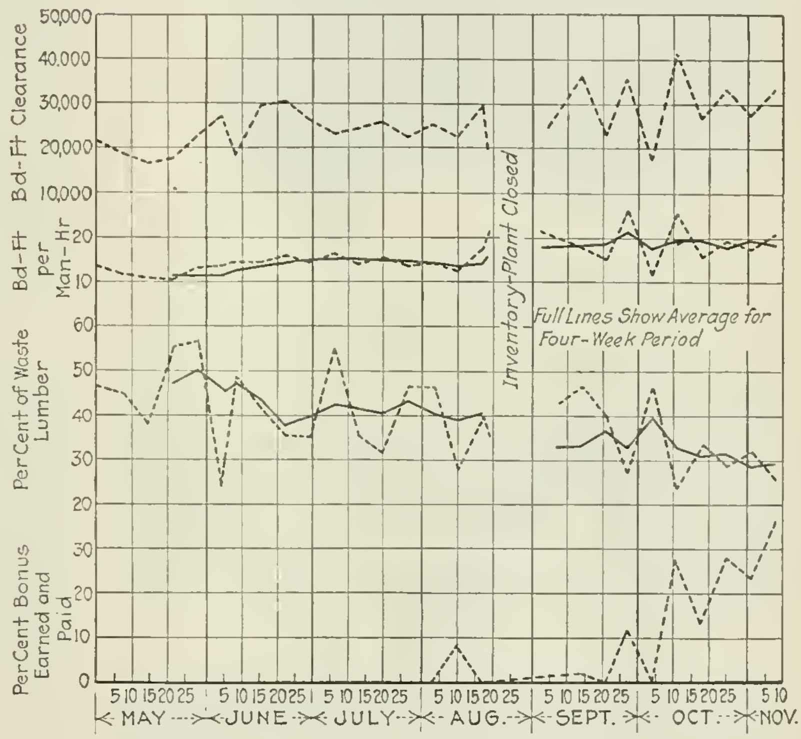

Fig. 3 Six Months' Results of Plan Outlined

they should be made into groups comprising the same or similar dimension stock of sufficient volume to enable the issuance of an advantageous manufacturing order. The head of the planning department should supervise the listing from these orders of quantities of dimension block sizes, to fill the orders and make up a dressed dimension-cutting schedule for at least a week ahead.

Continuous close touch should be maintained by the planning department with the part-stock inventory at all times in order that manufacturing orders and part-stock requisitions may be supplemented and filled out to an advantageous program in making out a dressed dimension-cutting schedule. Additional manufacturing orders should be issued for enough additional board footage of dimension stock in order that there will be balanced economy in the cutting, since some catalog units and their parts usually permit more advantageous dimensioning than others, and it is desirable to equalize the advantage week by week as much as possible for the lowest final average.

Installation of the Wage-Payment Plan. With the proper assortment of carefully dried lumber available and the cutting orders planned for widest possible range of sizes under the order require-

ments, the plan is explained to the personnel of the cutting department. During the investigation, records of intake, clearance and waste should have been installed. For several weeks a trained woodworking engineer should work continuously in the department, instructing and encouraging the workers.

For each pay period the net clearance of product from the department divided by the total number of hours worked by the standard crew gives the board-foot-per-hour production.

Waste Percentage	Production in Board-Feet per Man-Hour																				
	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30
36	0	2	2	2	2	2	2	3	3	3	3	3	3	4	4	4	4	4	4	4	5
35	0	3	3	3	3	3	4	4	4	4	5	5	5	5	6	6	6	6	6	7	7
34	0	4	4	5	5	5	6	6	6	7	7	7	8	8	8	9	9	9	10	10	10
33	0	6	6	7	7	8	8	9	9	10	10	11	11	12	12	13	13	14	14	15	15
32	0	7	8	9	9	10	10	11	12	12	13	14	14	15	16	16	17	18	18	19	20
31	0	9	10	11	11	12	13	14	15	15	16	17	18	19	19	20	21	22	23	24	24
30	0	11	12	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29
29	0	12	13	15	16	17	18	19	20	21	22	24	25	26	27	28	29	30	31	32	34
28	0	14	15	17	18	19	20	22	23	24	25	27	28	29	31	32	33	34	36	37	38
27	0	16	17	18	20	21	23	24	26	27	28	30	31	33	34	35	37	38	40	41	43
26	0	17	19	21	22	24	25	27	28	30	32	33	35	36	38	40	41	43	44	46	47
25	0	19	21	22	24	26	28	29	31	33	35	36	38	40	42	43	45	47	48	50	52
24	0	21	23	24	26	28	30	32	34	36	38	40	41	43	45	47	49	51	53	55	56
23	0	22	25	27	29	31	33	35	37	39	41	43	45	47	49	51	53	55	57	59	61
22	0	24	26	29	31	33	35	37	40	42	44	46	48	51	53	55	57	59	62	64	66
21	0	26	28	31	33	35	38	40	42	45	47	49	52	54	56	59	61	63	66	68	71
20	0	28	30	33	35	38	40	43	45	48	50	53	55	58	60	63	65	68	70	73	75
19	0	30	32	35	38	40	43	46	48	51	54	57	59	62	65	67	70	73	75	78	81
18	0	31	35	38	40	43	46	49	52	55	58	61	64	67	69	72	75	78	81	84	86
17	0	34	38	41	44	47	50	53	56	59	62	65	69	71	75	78	81	84	87	91	94
16	0	36	40	43	46	50	53	56	59	63	66	69	73	76	79	83	86	89	93	96	99
15	0	39	43	46	50	53	57	60	64	67	71	74	78	82	85	89	92	96	99	106	109

Standard Waste

Standard Production

Fig. 4 Bonus Percentages for Standard Range of Waste and Production

Net intake less net clearance divided by net intake gives the waste percentage.

Fig. 3 shows the results obtained in six months in the plant at which the charts shown in Figs. 1, 2 and 4 were used. These figures were recorded in 1921, therefore over a year has elapsed since the results were obtained. During this past year the standard condition of 26 ft. B. M. per hr. and 20 per cent waste has been bettered several times.

Fig. 4 shows the bonus percentage of standard wages, which, added to the standard wages, gives the total pay.

The Dollars and Cents Results

Suppose—and these are average conditions—that a plant is operating with a clearance of 12 ft. B. M. per man-hour, cutting wages of 50 cents an hour, and 45 per cent waste. The application of the bonus rate shown in Fig. 4 should result in the following saving for each 1,000,000 ft. B. M. of lumber used if the standard waste and standard production are attained:

Labor:
- Original Cost:
  - Hourly wages = \$0.50
  - Hourly production = 12 ft. B. M.
  - \$0.50/12 = \$0.042 per ft. B. M.
- Resulting Cost:
  - Hourly wages = \$0.50 + 65 per cent bonus = \$0.83
  - Hourly production = 26 ft. B. M.
  - \$0.83/26 = \$0.032 per ft. B. M.
- Saving per ft. B. M.:
  - \$0.042 − \$0.032 = \$0.01
- Saving per Million ft. B. M.:
  - 1,000,000 × \$0.01 = \$10,000

Material:
- Original waste = 45 per cent
- Resulting waste = 20 per cent
- Lumber saving = 25 per cent
- Lumber cost 1,000,000 ft. (\$70 per M.) = \$70,000
- 25 per cent of \$70,000 = \$17,500

Total Saving Per Million Ft. B. M.:
- \$10,000 (labor) + \$17,500 (material) = \$27,500

In a plant using 500,000 ft. of lumber a year, the above saving will represent an appreciable reduction in manufacturing cost.

TESTS OF TYPE W STERLING BOILER AT THE CONNORS CREEK POWER HOUSE

(*Continued from page 31*)

$$\text{For floating bank, lb. coal} = 8600 + 105x$$
$$\text{For dead bank, lb. coal} = 8000 + 280x$$

where x = number of hours banked. These equations give a greater amount of coal for a floating bank than for a dead bank for periods of less than four hours; but under actual conditions there is practically no difference between the two kinds of banks for the first portion of a banking period, so the equations are meant to apply only to banking periods in excess of four hours.

General. At the present writing seventeen boilers have been rebaffled according to arrangement "B," modified slightly in the arrangement of the cross-baffle at the top of the front baffle. The vertical baffle has been shortened about six inches and the cross-baffle at the top inclined upward at about 35 deg. from the front baffle. The results being obtained indicate that the superheated-steam temperature has been increased fully 50 deg. fahr. over that obtained with the original baffle, and that there is a decided improvement in the overall efficiency.

A study of the heat absorbed in the different passes of the boiler indicated that a rearrangement of tubes would be beneficial. This possibility was studied by the engineers of the Babcock and Wilcox Company and The Detroit Edison Company, with the result that the new boilers recently installed at the Marysville power house have in cross-section but five tubes between the upper center drum and each mud drum and ten tubes between each mud drum and the upper drum directly above. The boiler is baffled similarly to arrangement "B," except that there are two vertical baffles in each rear bank which direct the gases in three vertical passes after they leave the superheater pass. Economy results are not yet available, but it is believed that a decided decrease in the stack-gas temperatures will be realized.

Discussion

Dr. D. S. Jacobus,[1] said that it gave him great pleasure to discuss the paper, as it brought back recollections of a test that he had made at the Del Ray plant about ten years ago, and of the many courtesies and kindnesses extended to him at that time.

His results, Dr. Jacobus said, were consistent with those obtained by Mr. Thompson. William Kent, in discussing his paper, had pointed out that Dr. Jacobus' tests gave the highest efficiencies at high as well as low rates of driving ever obtained from coal having over 25 per cent of volatile matter, and it was indeed gratifying to note that the results were substantiated and that Mr. Thompson had secured somewhat higher efficiencies than those found in his tests. The efficiencies secured by Mr. Thompson at the lower ratings with the baffles arranged in the same way as in the Del Ray tests were the same as those which Dr. Jacobus had obtained. At the higher ratings Mr. Thompson's results were about 2 per cent higher than his, this difference, as shown by the heat balances, being due mainly to there having been a lesser loss through the carbon in the ashes in Mr. Thompson's tests. When corrected for the differences in the ash pit losses, however, the results agreed within one per cent, which was remarkably close when one considered the error that might be involved in estimating the condition of the fires at the beginning and end of a test with about 15 tons of coal on the grates.

The tests clearly indicated the advantage of changing the baffles. In addition to obtaining higher efficiencies the superheat was increased in the arrangement adopted for use and as a higher superheat could be made good use of, this was also an advantage.

He had visited the plant when Mr. Thompson's tests were in progress and could certify to the fact that they had been conducted in a most exact and scientific way. He had held up these tests on several occasions as an example of the sort of industrial research that should be encouraged by Engineering Foundation and the National Research Council, as they were a direct benefit in the problem of the conservation of fuel and to the engineer at large.

[1] Advisory engineer, Babcock & Wilcox Co., New York, N. Y. Mem. Am.Soc.M.E.

The Torsional Strength of Bars

By CONSTANTIN WEBER

Mathematical treatment of the torsional strength of bars, giving a general solution of the problem together with precise solutions for certain cases and approximate solution for others. The article was briefly summarized in the November, 1922, issue of Mechanical Engineering, but so many inquiries as to details have been received that it has been decided to publish a more complete abstract.

In the middle of the 19th century Saint-Venant developed a general differential equation for the torsion of bars; he also found exact solutions for a limited number of cross-sections. In practice, however, bars are encountered of cross-sections vastly different from those treated by Saint-Venant. Foeppl gave exact solutions for a certain number of these, in particular for thin-walled rolled shapes composed of long rectangles, but there are still a number of sections of considerable interest from a practical point of view which remain unsolved. The present article is an abstract of a research monograph (Forschungsarbeit Heft 249) published by the German Society of Engineers. It comprises fundamental equations for the torsional strength of bars, the more important exact and approximate solutions for various shapes, the influence of normal stresses in the axial direction at considerable twists, and the curvature of certain cross-sections. Among other things, several errors in engineering handbooks are pointed out.

General Solution

If a couple acts on a prismatic bar made of a material which is isotropic and behaves in accordance with Hooke's law, and if this couple acts at right angles to the axis of the bar, the bar becomes subject to torsion, the moment of torsion being, say, M cm-kg. Let now axes of reference x, y and z be passed through the body as shown in Fig. 1, so that the z-axis coincides with the axis of torsion.

The longitudinal fibers lying in the z-axis remains straight, while all the other fibers assume helical shapes about this axis. There are therefore shear stresses τ in the cross-sections of the bar which may be resolved into shear stresses τ_{xz} in the y-direction and τ_{yz} in the x-direction. Simultaneously, however, these shear stresses appear in the z-direction in longitudinal sections parallel to the y-z or x-y planes. The condition that all the forces acting on a particle in the z-direction should be in equilibrium gives—

$$\frac{\partial \tau_{xz}}{\partial x} + \frac{\partial \tau_{yz}}{\partial y} = 0 \qquad [1]$$

This equation is satisfied through—

$$\tau_{xz} = \frac{\partial f}{\partial y}, \quad \tau_{yz} = -\frac{\partial f}{\partial x} \qquad [2]$$

in which $\frac{\partial f}{\partial x}$ and $\frac{\partial f}{\partial y}$ are partial derivatives of a function—

$$f\,(x,y) = K \qquad [3]$$

For each value of K a closed line is obtained on the cross-section and the resultant shear stress coincides at every point with a tangent to this line (Fig. 2). Equation [3] is therefore the equation of the family of lines of shear.

Two contiguous lines of stress corresponding to the values of K and $K + dK$ delimit the closed strip of variable width dn which corresponds in the body to a tubular lamination (Figs. 3 and 4).

Since there are no forces acting on the walls of this tubular lamination it may be separated from the rest of the body. Referring to Fig. 4, the area ABB_1A_1 of this tubular lamination (of length unity) is acted on by a constant longitudinal shear force—

$$dK = \tau dn \qquad [4]$$

If we integrate the force dK we shall obtain for the inner shear line the value K_i and for the outer limit line the value K_a. The entire longitudinal shear force acting in this cross-section is then $K_a - K_i$.

The cross-sections of the bar originally plane become curved. The points on any line parallel to the x-axis are displaced in the z-direction. At the point xy the curved line forms with the original position of the line the angle—

$$\gamma_x = -\delta y + \frac{\tau_{xz}}{G} \qquad [5]$$

where G is the modulus of rigidity and δ the angle of torsion in a given length. Correspondingly the equation holds good for points lying on the lines originally parallel to the y-axis:

$$\gamma_y = \delta x + \frac{\tau_{yz}}{G} \qquad [5a]$$

In order that the internal arrangement of all the molecules consti-

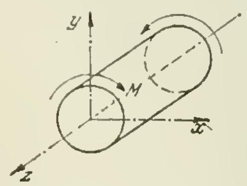

Fig. 1 Axes of Reference in a Bar under Torsion

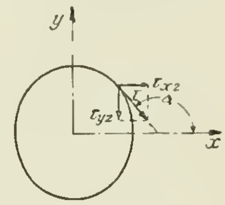

Fig. 2 Line of Shear

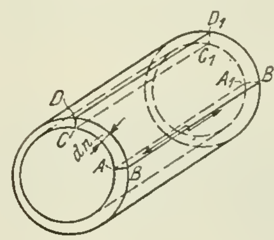

Fig. 3

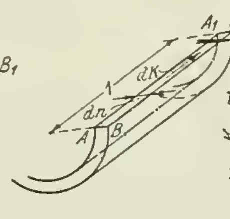

Fig. 4

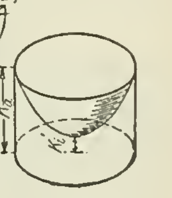

Fig. 5

Figs. 3 and 4 Longitudinal Shear in a Tubular Lamination
Fig. 5 Graphic Representation of the Moment of Torsion in a Bar

tuting the body remain unchanged, the following equation must hold good:

$$\frac{\partial \gamma_x}{\partial y} = \frac{\partial \gamma_y}{\partial x}$$

From this may be derived the equation of internal structure, namely,

$$\frac{\partial \tau_{xz}}{\partial y} - \frac{\partial \tau_{yz}}{\partial x} = 2G\delta \qquad [6]$$

Equations [2] and [6] give the differential equation for the family of lines of shear, or—

$$\frac{\partial^2 f}{\partial x^2} + \frac{\partial^2 f}{\partial y^2} = 2G\delta \qquad [7]$$

For the entire cross-section the equation for the family of lines of shear $f(x,y) = K$ must satisfy the differential equation [7], must always remain within the confines of the given cross-section, and must give the outer limit for the value $K = K_a$. In addition, for the case of a ring-shaped cross-section $f\,(x,y) = K_i$ must give the inside limit line, and the relation—

$$\int \tau dl = 2G\delta F \qquad [8]$$

must be satisfied as applying to the shear line surrounding the hole.

In this equation dt is the longitudinal differential of the corresponding lines of shear and F is the enclosed area. The integral extends over the closed line of shear.

The moment is obtained by integrating $y\tau_x df + x\tau_y df$ over the entire cross-section—

$$M = 2K_a F_a - 2\int\int f dx dy \qquad [9]$$

If over each point of the cross-section be plotted the heights $K = f(x, y)$, the body shown in Fig. 5 will be obtained. The moment is represented by double the volume of the funnel-shaped depression. In the case of ring-shaped cross-sections a truncated funnel is correspondingly obtained, but in both cases the moment may be expressed as follows:

$$M = 2\int_{K_i}^{K_a} F dK \qquad [10]$$

Where F is the area within the line of shear corresponding to the variable K.

The general solution of the differential equation [7] is given in

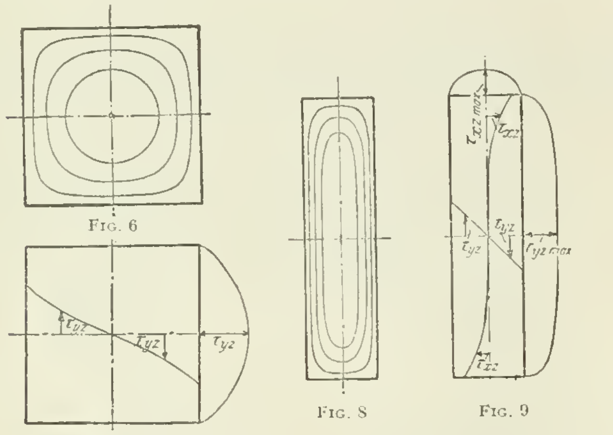

Fig. 6 Fig. 7 Fig. 8 Fig. 9

Figs. 6 and 7 Lines of Shear and Stresses in a Square Cross-Section
Figs. 8 and 9 Lines of Shear and Stresses in a Rectangular Cross-Section

$$f(x,y) = 2G\delta\left(\frac{x^2}{4} + \frac{y^2}{4}\right) + g_1(y + ix) + g_2(y - ix) = K \quad [11]$$

and the functions g_1 and g_2 must be so selected that the imaginary members will disappear. As examples of functions of $g_1(y + ix) + g_2(y - ix)$, the author cites the following:

Rational Algebraic Functions:

$$\tfrac{1}{2}\,[(y + ix) + (y - ix)] = y$$
$$\tfrac{1}{2}\,[(y + ix)^2 + (y - ix)^2] = y^2 - x^2$$
$$\tfrac{1}{2}\,[(y + ix)^3 + (y - ix)^3] = y^3 - 3yx^2$$

Trigonometric Hyperbolic Functions:

$$\begin{aligned}\tfrac{1}{2}[\cos a\,(y + ix) + \cos a\,(y - ix)] &= \cos ay \cosh ax\\ &= \cos ax \cosh ay\\ &= \sin ay \sinh ax\\ &= \sin ax \sinh ay\end{aligned}$$

In Polar Coördinates:

$$g_1(y + ix) + g_2(y - ix) = r^n \cos n\varphi$$

Here n may be any positive or negative number, fractional or integral.

Exact Solutions for Special Cases

Under this head the author discusses the solutions for a circular and elliptical cross-sections, an equilateral-triangle cross-section, and a rectangular cross-section. Only this latter will be presented here.

The author considers the case of a bar of rectangular cross-section of width a and height $h = na$ ($n \geqq 1$). The solution for the family of lines of shear is obtained by the use of a series of trigonometric hyperbolic terms:

$$2G\delta\left(\frac{x^2}{4} + \frac{y^2}{4}\right) + 2G\delta\left(\frac{x^2}{4} - \frac{y^2}{4}\right)$$

$$+ G\delta a^2 \sum_{k=1}^{k=\infty} (-1)^{\frac{k-1}{2}} \frac{\cosh\left(k\dfrac{\pi}{2}\dfrac{y}{{}^1\!/_2 a}\right)\cos\left(k\dfrac{\pi}{2}\dfrac{x}{{}^1\!/_2 a}\right)}{\left(\dfrac{\pi}{2}\right)^3 k^3 \cosh nk\dfrac{\pi}{2}}$$

$$+ c_1 = K$$

$$(k = 1, 3, 5 \ldots)$$

From this the moments and stresses may be calculated. Figs. 6 to 9 show the lines of shear and the distribution of stresses for a square and a rectangle with $n = 4$. The relation between the stresses, the moment and the dimensions of the cross-section may be expressed by means of auxiliary values ψ_1, ψ_2, etc. by the following equations:

$$\tau_{yz\,\max} = \tau_{\max} = \psi_1 G\delta a$$

Here $\tau_{\max}$ occurs at the middle of the long side. In long rectangles with $n>4$ the stress found close to the ends is zero)

$$\tau_{xz\,\max} = \psi_2 G\delta a$$

(This stress occurs at the middle of the short side)

$$M = n\psi_3 G\delta a^4$$

$$M = \frac{\tau_{\max} a^2 h}{\psi_4}$$

$$A = \psi_5 \frac{\tau^2_{\max} V}{G}$$

Here A is the work of deformation and V the volume of the bar. The longitudinal stress measured from the middle of the cross-section of the edge is—

$$K_a = \psi_6 G\delta a^2$$

The values ψ_1 to ψ_6 are presented in Table 1.

TABLE 1 VALUES OF ψ

n =	1	1.5	2	3	4	6	8	10	∞
ψ_1 =	0.6753	0.8476	0.9300	0.9854	0.9970	0.9999	$\sim$1	$\sim$1	1
ψ_2 =	0.6753	0.7279	0.7395	0.7423	0.7423	0.7425	0.7425	0.7425	0.7425
ψ_3 =	0.1404	0.1957	0.2286	0.2633	0.2808	0.2982	0.3070	0.3123	0.3333
ψ_4 =	4.81	4.33	4.07	3.74	3.55	3.35	3.26	3.20	3.00
ψ_5 =	0.1539	0.1362	0.1318	0.1357	0.1412	0.1491	0.1535	0.1562	0.1667
ψ_6 =	0.1472	0.2015	0.2277	0.2454	0.2491	0.2500	0.2500	0.2500	0.2500

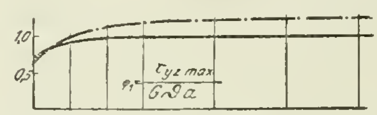

Fig. 10 Comparison of the Values of ψ_1 as Obtained by the Author and as Given in the Hutte Engineerimg Handbook

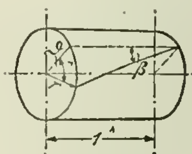

Fig. 11 Torsional Deformation of a Bar

For the most important of these values, namely, ψ_1, ψ_3 and ψ_4, the following approximate equations can be used:

$$\psi'_1 = 1 - \frac{0.65}{1 + n^3} \text{ (error} < 0.8 \text{ per cent)}$$

$$n\psi'_3 = \frac{1}{3}\left((n - 0.630 + \frac{0.052}{n^4}\right) \text{ (error} < 0.5 \text{ per cent)}$$

$$n\psi'_4 = 3 + \frac{1.8}{n} \text{ (maximum error, approximately 4 per cent)}$$

The author plots the values from the above table in a series of curves such as, for example, Fig. 10, and side by side in broken lines plots from the Hütte Handbook (22nd German edition, pp. 569–571) the values commonly accepted. It is of interest to note how far apart the two are. The values for A in the above formula in Hütte (same edition, pp. 597–598) appear to be likewise wrong.

Approximate Solutions

A series of approximate solutions are given covering various ring-shaped cross-sections, strip-like sections and composite sections. In arriving at these solutions the author uses the differential equation [7] for the family of lines of shear and by transforming it into one expressed in polar coördinates he obtains—

$$\frac{d\tau}{ds} + \frac{\tau}{\rho} = 2G\delta \qquad [12]$$

where ρ is the radius of curvature of the line of shear at a given point,

τ the stress, and $d\tau/ds$ the differential of the latter normal to the direction of stress.

Deformation Resulting from Torsion

Axis of Rotation. As a result of torsion longitudinal fibers of the bar assume a helical shape about the axis of rotation. In the case of small torsions such as occur ordinarily, the angle of inclination β of the helices (Fig. 11) to the axis is so small that for a finite length of bar each of these helices does not noticeably differ from a straight line and therefore each fiber may be considered as an axis of rotation.

In the case of greater rates of torsion the angle β of the outer fibers is greater and they can no longer be considered as lying in a straight line. In this case a given longitudinal fiber becomes the axis of twist, and a point in the cross-section of the bar the center of twist. Because of their stretch the outer fibers are subjected to tensile stresses, and if no force is acting on the bar in the longitudinal direction the fibers in the neighborhood of the axis of rotation are under compression. The center of torsion is at the point where no bending moment is produced by the longitudinal stresses. In polysymmetrical sections the center of torsion coincides with the center of the geometric figure, but this is not the case with non-symmetrical or simple symmetrical cross-sections. The normal stresses are expressed by—

$$\sigma_z = \frac{1}{2} E\delta^2 \left(r^2 - \frac{J_p}{F}\right)$$

where J_p is the polar moment of inertia with reference to the center of rotation, F the area of cross-section of the bar, and r the distance from the center of rotation. The stresses σ_z increase as the

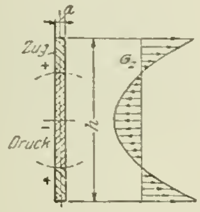

Fig. 12

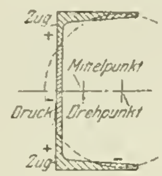

Fig. 13

Figs. 12 and 13 Normal Stresses at Twists of Considerable Magnitude

(*Zug* = tension; *druck* = pressure; *mittelpunkt* = center· *drehpunkt* = center of rotation.)

square of δ, while the stresses τ vary directly as δ. For small values of δ, τ is the most important stress and it is only when δ becomes large that σ_z takes on significance. Figs. 12 and 13 show the distribution of normal stresses in a long rectangular cross-section and in a channel cross-section. In the latter it is clear that the center of rotation does not coincide with the center of gravity. From this it follows that the statement in the Hütte Handbook (22nd German edition, p. 568), namely, "the center of the arc of torsion, i.e., the point on the cross-section which is not subject to displacement by the moment and in which, therefore, the shear stress is equal to zero, is the center of gravity," does not apply to all cases. Neither does the center of rotation always coincide with the center of gravity, nor is the stress τ at the center of rotation or center of gravity equal to zero.

In the center of rectangular sections with large values of the ratio n between the sides, $J_p \sim J_y$ and $p \sim y$. Because of this,

$$\sigma_z = \frac{1}{2} E\delta^2 \left((y^2 - \frac{1}{12} h^2\right);$$

$$\sigma_{z\,\max} = \frac{1}{12} E\delta^2 h^2; \; \sigma_{z\,\min} = -\frac{1}{24} E\delta^2 h^2$$

If $\tau \gtrless 1000$ kg. per sq. cm., $E = 2{,}150\,000$ kg. per sq. cm., and $G = 83{,}000$ kg. per sq. cm., the normal stress ψ_z has to be taken into consideration when $n > 40$ or thereabouts. Through the stress σ_z is transmitted the additional moment of torsion M_z. In the minute area of cross-section df distant r from the center of rotation, the force acting thereon is $\sigma_z df$. As the fiber forms at this point the angle $\beta = \delta r$ with the axis of rotation, we have a partial force $\beta\sigma_z df$ acting on the plane of the cross-section and creating a moment $r\,\beta\sigma_z df$. For the entire section the moment is—

$$M_z = \int r\beta\sigma_z df = \frac{1}{360} E\delta^3 n^5 a^6$$

where n is the ratio of the lengths of the sides of the rectangle and a the width of the rectangle. The moment transmitted by the shear stress and the normal stress is—

$$M_s = \frac{1}{360} E\delta^3 n^5 a^6 + \frac{1}{3} G\delta n a^4$$

The deformation A_z due to the normal stress is for the length of bar l,

$$A_z = \frac{1}{4} M_z \delta l$$

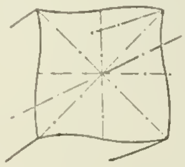

Fig. 14

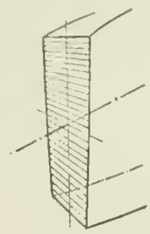

Fig. 15

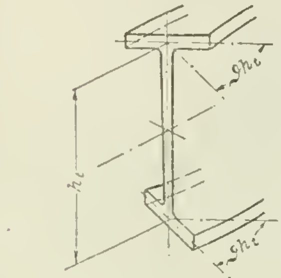

Fig. 16

Figs. 14–16 Curvature of Square, Rectangular, and I-Beam Cross-Sections

while the work of deformation due to the shear stress is determined by the usual formula—

$$A = \frac{1}{2} M_z \delta l$$

Curvature of the Cross-Section

Because of the presence of the moment of torsion the originally plane cross-sections of the bar become curved, only circular and circular ring cross-sections remaining plane. In symmetrical cross-sections the lines of symmetry remain straight. Thus, Figs. 14 and 15 show respectively the curvature of a square and of a long rectangular cross-section. The width lines of this cross-section remain at all points approximately at right angles to the longitudinal fibers of the bar which are here twisted to helices. Fig. 16 shows the curvature of an I-beam cross-section.

Some of the conclusions at which the author arrives are as follows: A homogeneous, elastic prismatic bar is stressed by a couple the plane of which is normal to the axis of the bar. This leads to a twist of two cross-sections of the bar located at a distance of 1 cm. apart through a relative angle δ.

The shear stress τ and the moment of torsion M are functions of and may be expressed by the dimensions of the cross-sections, the modulus of rigidity G and the angle δ in accordance with the formulas given in the November, 1922, issue of Mechanical Engineering on pp. 738–739. The functional relation between $\tau_{\max}$ and M depends on the distance for which δ is measured.

The original article gives a table containing expressions for the moment of torsion and stresses in bars of various cross-sections—twenty in all. This table was published in the November, 1922, issue of Mechanical Engineering, pp. 738–739, and is therefore not reprinted here.

Attention is here called to the fact that a correction should be made in this table: namely, the last formula in the column "Moments for Cross-Sections," No. 16, should read—

$$l_{t2} = l_2 - 1.67 s_f + 1.76 s_s.$$

(*Zeitschrift des Vereines deutscher Ingenieure*, vol. 66, nos. 31–32, Aug. 31, 1922, pp. 764–769, 35 figs. and an illustrated table, *tpA*)

Short Abstracts of the Month

AIR MACHINERY

Some Elements in Air Compression, W. Carter. A paper chiefly of a practical character discussing the essentials of construction of the air compressor and method of using it. Only a few features will be referred to here.

In discussing the various methods of drive, in particular, belt drive on close centers, the author calls attention to a recent development, namely, an arrangement involving the use of a floating idler pulley and a very slack belt. The weight of the idler takes up the slack of the belt and increases the arc of contact on the driving and driven pulleys so that the full power is transmitted without any undue strain on the bearings or on the belt itself.

A very modern development is the direct-connected electric-driven air compressor with the rotor of a synchronous motor mounted directed on the compressor shaft. This construction is not applicable to smaller units than about 700-cu-ft., 100-lb.-pressure compressors, because the cost for direct connected synchronous motors of smal' power becomes excessive. On moderate- and large-sized machines, however, this design affords the very highest possible economy. Recent improvements in air-valve movements and in air-cylinder design which permit much higher piston speeds than ever before were considered practical, have contributed to the success of the direct-connected compressor unit of this design. Unless the valve and port areas are very large, the compression efficiency is so greatly reduced at the customary speeds as to offset the advantages of compactness. The choice of a direct-connected motor-driven air compressor should therefore be determined by an investigation as to whether the compressor had been specially designed for this method of drive. (*Canadian Railway Club*, vol. 21, no. 7, Oct., 1922, pp. 19–39, *p*)

Multi-Stage Fan-Type Blower. Description of blowers of a new type made by the Syracuse Industrial Gas Co., Syracuse, N. Y. As shown in Fig. 1, the blower is essentially composed of three machines all located within the same casing. The air or

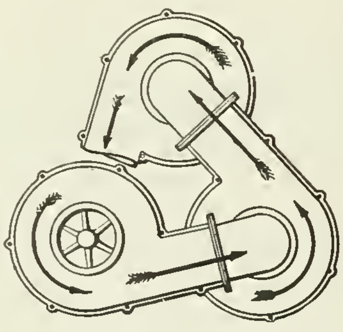

Fig. 1 Multi-Stage Fan-Type High-Pressure Blower

gas passes from fan to fan, each fan boosting the pressure in the same way as if it were a single-stage machine. The machines now built give pressures up to 2 lb. in small units. (*Forging and Heat Treating*, vol. 8, no. 10, Oct., 1922, pp. 484–485, 2 figs., *d*)

ENGINEERING MATERIALS (See also Special Processes)

The Influence of Phosphorus on Brass, A. Portevin. Tests were made on two series of brasses with an increasing proportion of phosphorus added in the form of phosphor copper containing 10 per cent of that element. The first series averaged 68 per cent copper and the second 58 per cent. Tests were made from both series cast in sand and in chills, the latter in the form of round brass $1^3/_4$ in. in diameter.

From these tests it was found that the mechanical properties are not sensibly affected as long as the phosphorus content remains below 0.05 per cent. When the proportion of phosphorus exceeds 0.5 per cent, a rapid fall in ductility and elongation takes place. (From the two tables given in the article it would appear that for some reason or other the phosphorus content was varied by big jumps. Thus, in one series of sand-cast tests the phosphorus content varied from nothing to 0.077 and in the next series from 0.51 to 1.47, there being nothing to indicate the behavior of the metal within the wide range of variation between 0.077 and 0.51.)

Among other things these tests have clearly demonstrated the danger of considering mechanical tests from the point of view of a few figures or a few properties only. As the phosphorus content is increased the metal becomes brittle, and the great decrease in ductility shows how unreliable are the ultimate tensile strength and the apparent elastic limit when considered alone. The tests have also shown the great differences resulting from the rate of cooling, and how useless it is to consider the results furnished by test prices that have been cast separately as indicating the quality of a casting. (Paper presented to the Nancy Congress of the Association Technique de Fonderie, abstracted through the *Foundry Trade Journal*, vol. 26, no. 323, Oct. 26, 1922, p. 344, *e*)

FORGING

Power-Plant Cost of Operating Hammers, R. E. Waldron. The variations in steam consumption for a given size of hammer depend entirely upon the condition of the hammer relative to its state of repair and valve adjustment. Another very important item is the condition of the cylinder and piston rings. The main valve may be set in such a way that the hammer will operate satisfactorily as a tool, but not economically from the point of view of steam consumption.

The author gives four curves to show steam consumption per hour for hammers from 1000 to 8000 lb., the data being taken from various tests. The results vary considerably depending upon the condition of the hammers, which makes it impossible to state what the actual consumption of any particular size of hammer is.

The author indicates a way for obtaining a basis for the comparison of steam costs for hammers.

One feature of importance has been brought out by analyzing the test results for the four hammers and, that is, that it is more expensive per 100 lb. of falling weight to operate small steam hammers than large ones.

Furthermore, steam consumption, or rather steam costs on a hammer, is greatly affected by conditions of operation, and is much less in shops working 24 hr. per day than in single-shift shops. (*Forging and Heat Treating*, vol. 8, no. 10, Oct., 1922, pp. 474–476, 7 figs., *t*)

FOUNDRY

Magnesium Castings, Carl Irresberger. A general discussion of magnesium and its alloys, together with practical data on casting articles from these metals and on the physical properties of magnesium castings.

Iron crucibles with gastight iron covers are recommended for melting magnesium and electron metal, these metals, unlike aluminum, having no tendency to attack iron. On the other hand, magnesium and its alloys even at comparatively low temperatures become plastic and from that point on manifest an increasing tendency to absorb gases of all kinds, which makes a reliable gastight cover on the crucible a basic condition of success in melting. Graphite crucibles should not be used, as magnesium absorbs from them considerable amounts of silicon.

Molds for magnesium castings may be made in sand, but satisfactory results have also beeen obtained with permanent iron molds. In order to avoid the danger of explosions, the molds should be thoroughly dried, say, at a temperature of 450 deg. cent. (842 deg. fahr.), at which temperature the chemically combined water in the clayey parts of the sand is driven out. Plenty of risers of generous proportions should be provided.

Extreme care should be taken not to leave any moisture in the mold. At high temperatures magnesium forms with water or water vapor white magnesium oxide and hydrogen, and the latter, together with air, forms a highly explosive mixture which is easily ignited by contact with the hot metal.

The article discusses magnesium foundry methods in considerable detail. It would appear that magnesium castings may show various colors on the outside, which depend apparently on the temperature of pouring and the degree of dryness of the mold. If the metal was poured at a correct, not excessively high, temperature in perfectly dry molds, the exterior skin of the casting should be of a silvery color. If poured at an excessively high temperature it will be of a bluish iridescent color, probably because of absorption of some silicon from the sand. If the temperature of pouring was right and the mold was not perfectly dry, a dirty grayish color will be shown, but in any event a brilliant silvery white may be imparted to the casting by pickling it in nitric acid of density 180 deg. Baumé, free from chlorine.

For castings magnesium is chiefly used in the form of electron metal which contains from 90 to 99 per cent of magnesium and from 10 to 1 per cent of a metal such as aluminum, zinc, magnesium or cadmium. They machine much better than aluminum and are used in particular where lightness of the part is a material consideration. Magnesium alloys have been used for perforated plates in textile machinery where the plate has to carry thousands of fine holes and where the slightest imperfection in the casting would make the product worthless. They proved to be perfectly satisfactory for this purpose. Magnesium alloys have been also used for spindles, one advantage being that owing to their lower weight as compared with iron they can be brought to speed in one third the time required for the latter. (*Giesserei Zeitung*, vol. 19, no. 41, Oct. 17, 1922, pp. 599–602, *p*)

GAS PRODUCERS

The Treat Gas Producer. Description of a mechanical gas producer invented by F. H. Treat. The chief distinctive features of this producer consist in a number of devices and power-actuated mechanisms which perform automatically various functions in relation to the fuel bed. Thus, a mechanism is provided for agitating the fuel bed and for feeding and distributing the fuel in the producer chamber. The machine to do this is located in the central circular opening of the producer top and is arranged to revolve bodily at a slow rate in a horizontal direction. The action for feeding and distributing the fuel and the agitation of the fuel bed functions in unison with the rotary movement.

The machine has a number of agitator bars extending vertically within the producer chamber so that the pair of agitator fingers of the lower ends penetrate the fuel bed. By turning adjusting screws the agitator bars may be raised and lowered at the will of the attendant. Fuel-feeding devices are provided. The blast is supplied through eight independently controlled steam-jet blowers of special design which are disposed uniformly around the outside of the producer. To each blower is connected an independent tuyere pipe which is arranged to extend through the tapering lower portion of the producer body and into the ash zone. The ashes are discharged through a water seal over the edge of the ashpan and a scraper device is employed which is designed to act against the interior surface of the ashpan.

The original article describes the various mechanisms in detail and illustrates some of them. No data of tests or performances in practice are given. (*Iron Trade Review*, vol. 71, no. 20, Nov. 16, 1922, pp. 1351–1354, 3 figs., *d*)

MARINE ENGINEERING

Wind-Propeller Drive for Boats

Driving a Boat against the Wind by an Air Motor. Description of the experiments of Constantin Joessel and Daloz on driving a 6-ton fishing vessel by wind force in any direction, i.e., with or against the wind. It is obvious that this could not be done by means of sails in which the pressure is always normal to the sail and a motor of the windmill type had to be used. In this motor, which is of the variable-propeller type, it is necessary on one hand to consider the pressure exerted by the wind on the system in motion, and on the other the energy of rotation obtained on the axis by the movement of the blades, this energy being transmissible to a suitable propeller. The water propeller like the air propeller gives an axial thrust which is a function of the energy of rotation that it receives. In order, therefore, to drive a boat it becomes necessary to create conditions under which the axial thrust of the water propeller will be greater than the component along the axis of the ship of the axial thrust due to the movement of the air propeller. If the axial thrust of the water screw be greater than the total axial thrust of the air propeller, the boat will be able to move against the wind.

Calculations and tests made on a small apparatus with fans as the source of the wind have shown that the problem was capable of solution provided the screws have suitable dimensions and are connected in such a manner as to produce a suitable speed ratio.

As a first step it was necessary to determine the number of blades in the air propeller that would give the best efficiency. Numerous tests have shown that the two-blade propeller is the best.

In the installation on the *LeBois-Rosé*, a fishing vessel of 6 tons capacity, the air propeller is 9 meters in diameter and the blades are made of laminated wood. The water propeller, is of the 4-blade type, made of bronze, and 1.05 meters in diameter. Both the air and water propellers are of variable pitch. In order to save expense in installation there is no speed-gear change between the air and water propeller, such as was used in preliminary tests. This lowers the efficiency of the boat, but it is still perfectly able to run into the wind or across it.

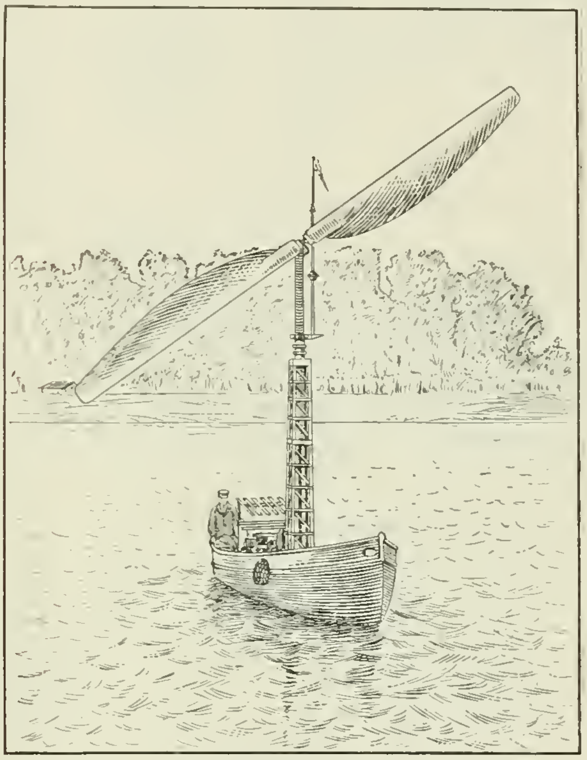

Fig. 2 Air-Screw-Propelled Vessel Capable of Breasting the Wind

The shifting of the air propeller, which must always be in a position normal to the wind, is effected by means of a worm gear which the pilot can operate simultaneously with the steering gear. It would be possible, however, to make the air propeller take its position automatically. In the experimental vessel serious difficulties arose due to the fact that the weight of the superstructure proved to be quite great and that the reaction of the wind on the propeller located at the top of the tower serving as a mast gave rise to a couple of considerable magnitude. It is claimed, however, that with suitable devices provided to take care of this situation, the boat has proved to be highly maneuverable, and with one man on board has been able to navigate successfully a crowded part of the River Seine between Sèvres and Saint-Cloud. The general appearance of the boat may be judged from Fig. 2. No data of the actual speeds attained with the various wind velocities are given. (Paper before the French Academy of Sciences, read Oct. 23. Abstracted through *Le Génie Civil*, vol. 81, no. 19, Nov. 16, 1922, pp. 421–422, 1 fig., *dA*)

MACHINE DESIGN AND PARTS

Gear Noises and Their Causes—Apparatus for Detecting Errors in Gears

Some Causes of Gear-Tooth Errors and Their Detection, K. L. Herrmann. The author analyzes the different gear noises and their causes and comes to the conclusion that production variables have a much greater influence on gear sounds than the changing pressure angles used or tooth-form detail.

The first of the gear noises discussed by the writer is a knock that

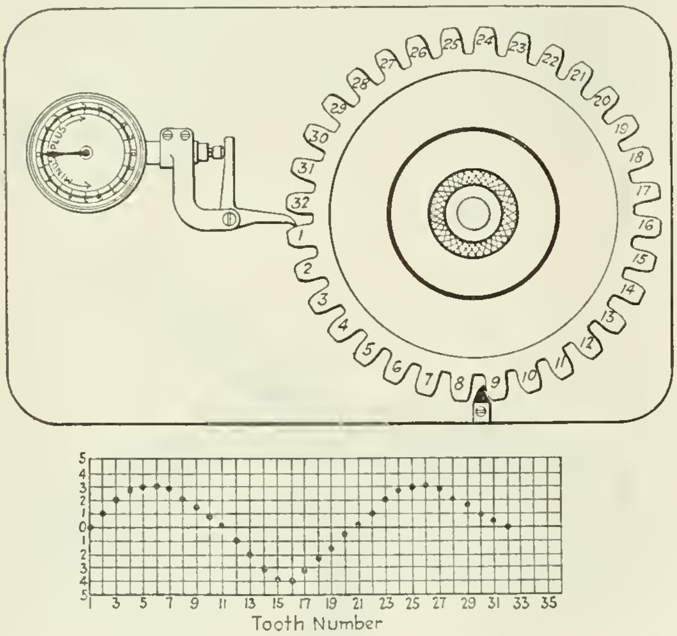

Fig. 3 Device Used for Checking Tooth Spacing and (Underneath) a Chart Showing the Results Obtained

in. from tooth to tooth. With eight successive teeth each gaining 0.001 in. on the side of the gear and a similar number of teeth that may be loosing 0.001 in., a total error of 0.016 in. might be imparted to the driven gear.

Fig. 3 illustrates a very simple device that has been used for checking tooth spacing. The gears are mounted on a bushing and one tooth comes against a stop. A dial indicator is arranged so as to be in contact with some tooth one-fourth, one-third, or one-half way around the gear. When the dial indicator is set at zero, with the tooth against the top at any one point, the distances between the two points can be measured and, if the gear be correct for indexing, placing any of the two teeth in the gear in similar positions should not cause the dial indicator to vary, especially if the gear runs true.

When the gear is first put on the indicating apparatus, the dial indicator is set at zero. A mark is then put at zero on the chart in Fig. 3. for tooth No. 1. The next step is to index the gear around to one tooth. Any reading obtained is marked above the tooth in vertical line. The gear is next indexed around to tooth No. 3 and the dial indicator reading is marked opposite the number of thousandths of an inch that it may show. The gear is then indexed to teeth Nos. 5, 6, etc., until all the teeth on the gear have been indexed.

For the purpose of record, we now have a chart showing the accumulated variables. It will be seen from Fig. 3 that at no point is the spacing variable as great as 0.001 in. between any two teeth, but it can be in error a total of 0.008 in. or more when the error between the several teeth has accumulated. A better visual demonstration of this condition occurring in gears is made by means of a gear-tooth-form projector. When a gear-tooth form is projected upon a screen by this device, it will be noted that the magnification of the shadow is 100 to 1, and that for every inch on the screen there is at least a 0.001-in. error somewhere in the gear. The shadow on the screen also shows the variation in uniform movement of the driven gear due to an error of this kind; that is, the driven gear, instead of having its tooth in the position of the outline on the screen, has been forced to advance a number of thousandths of an inch. It will be noticed, further, that this advance and retardation

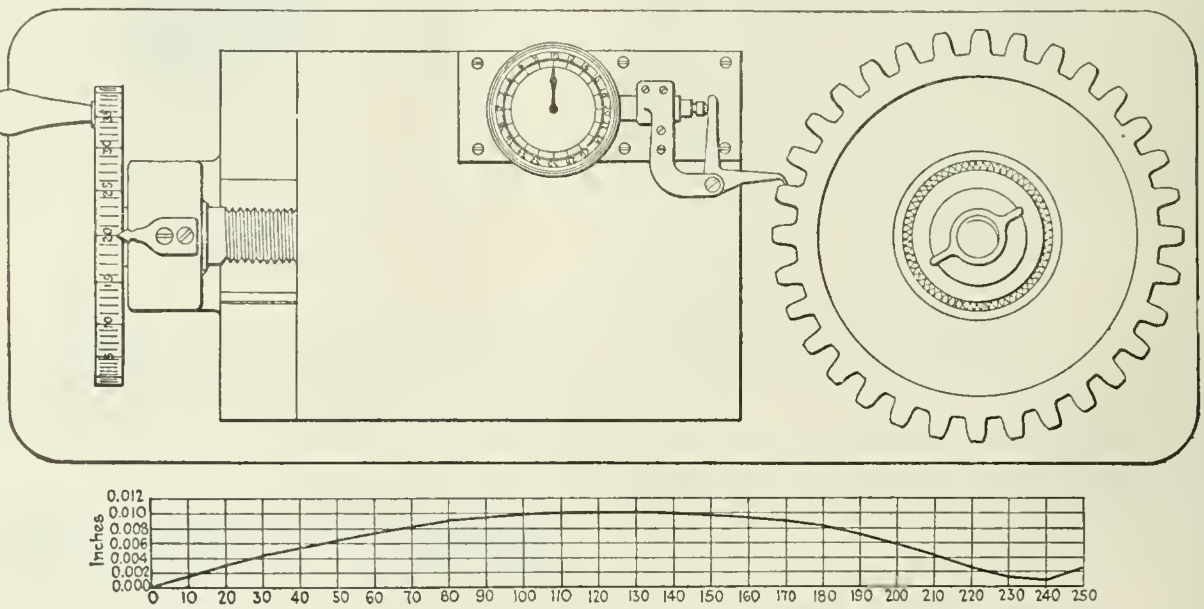

Fig. 4 Instrument for Obtaining an Analysis of Tooth-Forms Producing Noise and a Chart Showing the Outline of a Particular Tooth

might be caused by a nicked tooth or a single tooth of a pair of running gears that are in mesh. The same result may be produced by inaccurate conditions in the gears. For example, should the tooth spacing in a transmission drive pinion be such that the driven gear instead of rotating at a uniform speed is forced to increase or decrease its speed at every revolution of the pinion, there will be a noise. To avoid this it is not sufficient to check gears for spacing error from tooth to tooth. It is very desirable to check the accumulated error of a number of teeth because a gear may vary 0.001 does not occur uniformly; that is, the advance may be confined to a very small number of teeth, remain there for a certain length of time, and then be retarded slowly. A gear in this condition will give a rattle very similar to that which might be produced by unequal spacing. This condition can be studied best by charting it as described.

In addition to the two gears having a rather irregular action between themselves, their increasing and decreasing movement is carried on to the countershaft and the idler which often have similar

defects in themselves. Accumulating errors in gears often cause the fourth gear in a train to be as much as 0.025 in. away from its correct position. The countershaft then does not rotate smoothly and the gear at the other end of the countershaft in addition to the variable movement given it by the errors in the first two gears imparts its error to the gear meshing with it.

Fig. 4 shows an instrument developed by the author for the purpose of analyzing tooth forms producing the various sounds. It consists of a dial indicator mounted on a guided slide. The gear is placed in a definite position with respect to the indicator, when the operator starts at the point of the tooth and sets the indicator at zero. The slide is then moved toward the gear 0.010 in. and the indicator reading marked on the chart shown in the lower portion of Fig. 4. The slide is then moved 0.010 in. more, the reading is marked again, and this is continued until the bottom of the tooth is reached. By taking the gear that has just been charted off the bushing and placing another gear in its place, other tooth forms will be compared with the first.

The causes of the errors in gears referred to are various, some of them occurring in hardening, some of the cutting machines, and some in the cutters. To show this the author discusses the case of the hobbing machine and its possibilities for error, and also gives charts showing the conditions of the gear before and after hardening. From this it would appear that at times the hardening errors compensate for the cutting errors, while at other times the hardening errors cumulatively add themselves to the cutting errors. (*Journal of the Society of Automotive Engineers*, vol. 11, no. 5, Nov., 1922, pp. 391–397, 14 figs., *eA*. Abstract in *Automotive Industries*, vol. 47, no. 18, Nov. 2, 1922, pp. 869–873, 14 figs.)

MACHINE DESIGN

Epicyclic Gears and Gear-Ratio Diagram

Epicyclic Gears: the Gear-Ratio Diagram, P. Cormack. A diagram intended to be used for computing speed ratios of an epicyclic gear set. It is said that this diagram gives complete generality to the solution of problems on wheel trains and shows the properties of trains when used epicyclically. The diagram may also be applied to rotational accelerations.

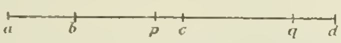

Fig. 5 Cormack Gear-Ratio Diagram

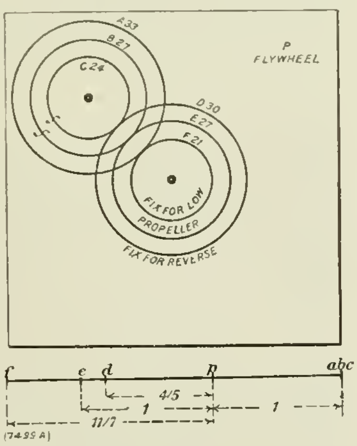

Fig. 6 Ford Epicyclic Gear and Gear-Ratio Diagram

Gear-Ratio Diagram. If the segments $p\,a$, $p\,b$, $p\,c$, $\ldots$, $p\,q$ of a line, Fig. 5, be proportional to the speeds of the wheels A, B, C, $\ldots$, Q, of a wheel train when P is fixed, then the segments $q\,a$, $q\,b$, $q\,c$, $\ldots$, $q\,p$, are proportional to the speeds of the wheels A, B, C, $\ldots$, P, when Q is fixed. A formal proof of this proposition may be obtained by considering the fixing of Q as being due to the imparting to the whole train of a motion equal and opposite to that possessed by Q. Thus, let a rotation $q\,p$ be added to the rotation $p\,a$, $p\,b$, $p\,c$, $\ldots$, $p\,q$, of $A, B, C, \ldots Q$, and P. The resultants are:

$$\begin{aligned}
\text{Rotation of } A &= q\,p + p\,a = q\,a \\
\text{Rotation of } B &= p\,q + p\,b = q\,b \\
\text{Rotation of } C &= q\,p + p\,c = q\,c \\
\text{Rotation of } Q &= q\,p + p\,q = 0 \\
\text{Rotation of } P &= q\,p + 0 = q\,p
\end{aligned}$$

Hence the proof.

Application to Epicyclic Gear Set. As an example the author shows how the gear ratios of the Ford motor-car transmission gear are exhibited by the diagram. This gear is shown in Fig. 6. The engine flywheel P carries the axle of the planet group $A\,B\,C$. B meshes with E, the propeller shaft; A meshes with F, which is fixed for the slow speed; and C meshes with D, which is fixed for the reverse. Taking P to be fixed, if A make one turn, so will B and C, since they are keyed to A. One turn of A gives $-33/21$ turns of F; one turn of B gives -1 turn of E; one turn of C gives $-24/30$ turns of D. To construct the gear-ratio diagram, therefore, draw $p\,a = p\,b = p\,c = 1$; $p\,f = -33/21$ or $-11/7$; $p\,e = -1$; $p\,d = -24/30$ or $-4/5$. We can now read off the low-gear ratio of the propeller E to the flywheel P, when F is fixed. It is $f\,e/f\,p$. Since $f\,e = 11/7 - 1 = 4/7$, and $f\,p = 11/7$, the low-gear ratio $f\,e/f\,p$ becomes 4/11.

With D fixed, as it is for the reverse gear, we have the speeds of the flywheel P and the propeller shaft E proportional to $d\,p$ and $d\,e$. The lines $d\,e$ and $d\,p$ being in opposite directions show that E and P revolve in opposite senses. Numerically $d\,e = 1 - 4/5$ or $1/5$, while $d\,p = 4/5$. The reverse gear ratio $d\,e/d\,p$ is therefore 1/4.

Angular Acceleration. Corresponding to the proposition of the second paragraph of this abstract for rotational velocities, we have the analogous proposition for rotational accelerations, a statement and proof of which is given in the second paragraph, if "angular acceleration" be written for the words "speed," "rotation," and "motion" occurring therein. (*Engineering*, vol. 114, no. 2965, Oct. 27, 1922, p. 511, *tp*)

MACHINE SHOP (See also Machine Design and Parts; Measuring and Testing)

Processing Spline Shafts by a New Method, James A. Ford. In this method a die is constructed according to the same principles that apply to the automatic threading dies now in general usage, the cutters being in the position that the die chasers ordinarily would occupy. The cam ring is practically of the same construction as that used on a threading die, except that the ring is made stronger. This opening feature is necessary on account of having to pass the shaft back through the die, because the body of the shaft beyond the splines is larger than the body portion between the splines, and the shaft will not pass completely through the die.

The shaft is entered into a bushing that is lined up with the die. Then the shaft is pressed through the die to a stop that has been set at a sufficient distance to permit the shaft to pass through to the shaft neck at the end of the splines. The cutters in the die are then released and the shaft is removed.

During the experiments with this die it was ascertained that a clearance angle on the cutter of 30 min. was about correct, and it was decided that one pass of the shaft through the die gave the most satisfactory result.

It is stated also that a method has been found to straighten the shafts to within 0.005 in. per ft. of being out of parallel with the true axis of the shaft. It is not stated how this was done. (*Journal of the Society of Automotive Engineers*, vol. 11, no. 5, Nov., 1922, pp. 433–434, 4 figs., *d*)

Manufacturing Distance Pieces. Description of machining processes and equipment. The piece is produced in four operations. First, the tube is cut to length in a press, next both ends are surface-ground in a surface grinder, then the hole is pierced in a press, and lastly the bore is ground in an internal grinder.

As to the first operation, namely, cutting the tube to length, the difficulty of preventing distortion under the shearing action must be overcome. This was accomplished by a device described in the original article in which the tubular stock is sheared.

The grinding of the ends of the tube, which is the second operation, is carried out in a surface grinder on a magnetic chuck. For the third operation a simple semi-automatic fixture described and illustrated in the original article is used.

Grinding the bore is the final operation, and in view of the fact that the internal dimensions are held to close limits, grinding is essential as it rectifies a slight distortion which may have taken place during the punching of the hole, and in addition removes burrs. This operation must be carried out carefully, as precaution must be taken to avoid the use of clamping devices that would cause distortion. For this purpose a special fixture has been designed, which is described and illustrated in the original article. (In this connection it may be noted that the fixture for internal

grinding is referred to as Fig. 4 in the text of the original article. It is really Fig. 3.) (*Engineering Production*, vol. 5, no. 109, Nov. 2, 1922, pp. 411–413, 3 figs., *d*)

MEASURING AND TESTING

Sound-Testing Devices—Testing Machinery by Sound

Detection, Location and Comparison of Sound, C. E. Noël-Storr. For a long time there has been an effort to build testing devices that would make it possible to determine and, in particular, locate irregularities in operation of machinery by the sound emitted.

The author developed his initial apparatus in order to locate mechanical defects in a series of very large engines which did not run quite right. To do this he devised an instrument with two ear pieces and flexible connections to the reproducer. While the device was crude and far from efficient, the difficulty in the engines was traced with very little trouble and with perfect comfort. Later on another problem arose in connection with small gear boxes which contained a double-reduction spur gear mounted on ball bearings. Some of these boxes failed to pass inspection on the ground of excessive noise. A difficulty also arose on account of the irregularity of the rejections, since batches considered noisy by the test room would perfectly pass, while nominally silent batches failed to do so, due, of course, to the entire lack of any definite standard of reference for either the inspector or the works staff. It therefore became desirable to find a way of measuring the sound of the boxes.

The construction of instruments for the detection and location of sound is complicated by the fact that in connection with mechanical work there are two distinct purposes for which such instruments may be applied, namely, the detection of internal or mechanical sound and external or atmospheric sound. For example, in examination of the running condition of the balls in a journal bearing the internal sound only is of interest and not any external noise the bearing may make. On the other hand, in many forms of construction it is desired to reduce the external noise to a minimum and it is quite possible that a test of the internal sound may lead in such cases to a totally incorrect conclusion.

To deal with the two different aspects of the matter there are two different types of reproducer. In the first place, there is the tectoscope, which is arranged with a test rod and reproduces only the internal sound of the bar with which the rod is in contact. The tectophone, on the other hand, is arranged with a conical mouth and reproduces the external sound when the mouthpiece is held close to any object.

It will be noted at once that one instrument serves to check the results obtained with the other. For example, the contact breaker of a magneto will show a considerable blow from the rocker arm when tested with the tectoscope, but except on a few very silent engines the blow will not be heard externally when tested with the tectophone. In other words, the first instrument will indicate that there is a distinct mechanical blow taking place, and the second test will show that in the matter of improving the general silence of operation this blow is of small moment.

The foregoing example serves to show that the clear reproduction of even minute internal noises should enable worn or faulty parts to be located quite easily, while it also brings forward the use of the second type of instrument for checking the amount of external noise arising from a given internal source. Thus parts which may give rise to external noises may be traced, although it is more than likely that in some cases the internal cause is of small magnitude.

There are other general applications of the tectophone; for example, there may be two universal joints on a common shaft, and either or both may be dry and noisy. In some cases of this nature the tectoscope applied to the nearest bearing on the shaft might fail to give a clear indication on account of the noise of the bearing, but if the tectophone is held quite close to each joint in turn the squeak can be instantly located. The above instance applies to many similar problems and includes the tracing of gas, compressed air, and similar leaks from pipes and plant in general, the flow of a liquid in the pipe being indicated quite distinctly by the tectoscope.

The author gives descriptions of ways to proceed in testing the operation of various parts of an automobile engine, selected here as an example, by means of his apparatus. Sounds picked up by this apparatus may be compared either with each other or with a standard which is to be taken as a fixed quantity. For general shop tests a pair of reproducers are used connected to the head frame. If, for example, the left-hand reproducer is placed in contact with No. 1 cylinder, the sound emanating therefrom will be the only sound audible to the operator. On placing the right-hand reproducer in contact with No. 3, however, the relative "slap" of the two cylinders can be instantly compared, this being preferable to an attempt to remember the relative intensity of No. 1 and making a mental comparison after testing No. 3.

It should also be noted that when required the method enables the internal sound to be compared with the external; and as in some forms of construction the section or shape of the casing may cause, say, four tappets and cams which are all of equal intensity internally to give very different external effects, the combined test should enable any confusion to be avoided as to the actual cause of the defect. In fact, it should be of considerable assistance in the industry for purposes as widely different as the choice of suitable material for the exhaust pipe and the design of a gear-box lid.

Other applications of the use of this apparatus are described, from which it would appear that by these means a considerable amount of information can be obtained at a small expense in time. For example, many sources of trouble in closed bodies can be easily obviated with the aid of the tectophone which will trace body squeaks, panel drumming, and the periodic drumming of wings and undershields under actual running conditions on the road. (Paper presented to the Coventry Branch of the Institution of Production Engineers, Nov. 7, 1922, abstracted through *Engineering Production*, vol. 5, no. 110, Nov. 9, 1922, pp. 439–443, 9 figs., *dA*)

MECHANICS (See Machine Design and Parts)

POWER-PLANT ENGINEERING (See also Forging)

Power-Station Design

Power-Station Design, C. W. E. Clarke, Mem. Am.Soc.M.E. Apart from market conditions for the sale of electrical energy, the author considers as the controlling factor in the selection of a power-station site the existence of an adequate supply of water for condensing purposes at all times, and from this point of view thinks that the so-called "mine-mouth" power plants would be of advantage in only very few locations.

The paper discusses the various features of design in considerable detail. Only a few points, however, can be reported here. The use of double stokers, that is, two stokers placed face to face, is seldom of advantage and the author considers it as justified only in cases where the boiler heating surface per square foot of floor area is very great, or when it is expected to operate boilers at very high ratings.

The use of pulverized fuel has only just passed the experimental stage, but there is little doubt that this system will be used in many of the plants built in the future, especially where only low-grade fuels are available. It has many advantages in efficiency and operating simplicity, but the additional cost of the system may militate against its wider adoption. Oil is the ideal fuel for use under boilers, but with the present relative costs of coal and oil it cannot be used economically for power-station work except in certain localities.

The installation of economizers, with fuel costs at their present level, is of doubtful advantage.

When increased building, economizer, induced-draft, fan, piping, maintenance, and operating costs are considered it will usually be found that an increase in the height of the boiler will result in a greater operating efficiency, considered financially, than if economizers are used. The curve in Fig. 7 shows a comparison between the efficiencies of a 15-high boiler with 64 per cent economizer and a 20-high boiler with no economizer. Every case should be considered in the light of its own peculiar conditions, but this curve is illustrative of the general trend.

Surface condensers are usually to be preferred to jet condensers because the pure condensate is available for boiler-feed purposes,

making elaborate systems for water treatment unnecessary. If there is a supply of good boiler feedwater available, which is rarely the case, a jet condenser is about as economical financially as a surface condenser. All surface condensers should be provided with some sort of screen to remove leaves and other matter from the condensing water. For this purpose a traveling screen is the only suitable apparatus. The water velocity through the free opening of screens should not exceed 2 ft. per sec., unless such a velocity requires extraordinarily large screens.

The only method left for improving the overall efficiency of a power station is through the system of heat conservation which goes under the general title of the "heat-balance system." Boiler design has reached a point beyond which little can be expected. Turbine generating equipment gives us efficiencies about as high as we can look for. We are then faced with the proposition of making the system of heat utilization in the station as efficient as possible. At best, there is only a little over 30 per cent of the energy put into the steam by the boiler which is available for conversion into power. The problem is how to approach as closely as possible to converting all this energy into power. This can be accomplished only by retaining in the station heat cycle as much as possible of the latent heat

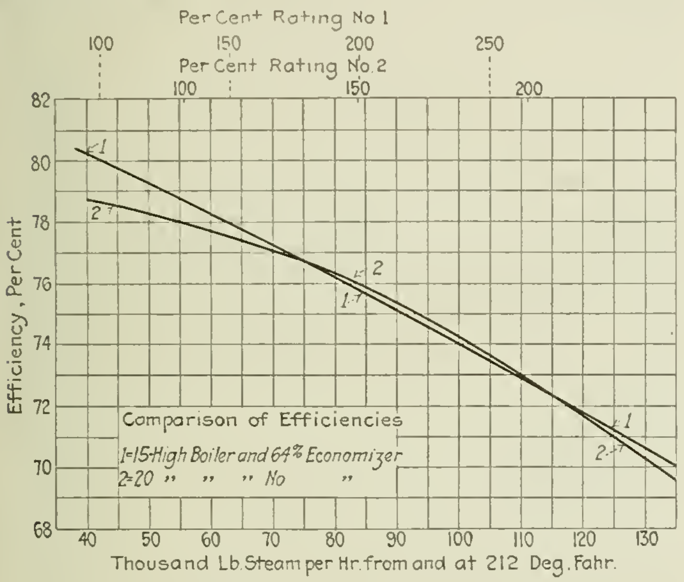

Fig. 7 Comparison of Boiler and Boiler-Economizer Unit

of the steam which ordinarily is transferred to the condensing water. A heat-balance system has this object in view.

There are four general methods of heat balance and the author discusses them in detail. For large stations he considers the following as the best system: House turbine, alternating current or direct current and electric drive for all but enough of the auxiliaries to keep the station running in case of accident to the house turbine and main generator.

Among other things, the article contains an interesting table giving piping and fitting schedules, as well as pipe materials best adapted for use in power-station work. (*Proceedings of the Engineers' Society of Western Pennsylvania*, vol. 38, no. 4, May, 1922, pp. 109–127, 1 fig. and 1 table, and discussion, pp. 128–167, 10 figs., *g*)

Slag on Boiler Tubes

Formation of Slag on Boiler Tubes, Harry H. Bates. The author claims that slag formation on boiler tubes and walls is essentially governed by the same rules as apply to clinker formation, and points out that in slag the iron must be kept in the ferric state, which is practically infusible. This can only be done by completely oxidizing the sulphur and iron before the tubes are reached.

All types of stokers have difficulty with slag formation and it is believed that slag particles are carried up with the draft in such minute form that they can be transported by the low-velocity gas as well as by the gas that rises rapidly.

An examination of the slag under the microscope revealed small spherical globules, substantiating the belief that the particularly troublesome particles were the small ones.

When these small particles come in contact with the free oxygen in the furnace gas for a sufficient time to oxidize them completely, they will be transformed into their completely oxidized state and become solid. If they solidify before touching the tubes or walls, they are carried through the boiler as solid ash. On the other hand, no free oxygen is obtained through the fuel bed. In this event the particles remain in a molten condition, on account of their low fusing temperature in their their -ous state, and are deposited on the tubes and walls where they may either be completely oxidized and solidified or be covered by successive coatings or layers of the same plastic material.

That the latter is true to a large extent is shown by layers of a very dark vitreous material covered by a reddish brown layer or protective coating. This reddish coating is largely ferric material and it prevents further oxidation of the dark ferrous material within by excluding the oxygen from it. A considerable portion of the material on the outer surface, especially on the tubes, is of a friable and nonfusible character, and it is of a completely oxidized nature.

The author calls attention to various efforts made for producing complete combustion in large furnaces, but points out that even if some efficient means is developed for mixing the gas and excess air together, it is very questionable whether the slag difficulty will be entirely overcome. It is to be remembered that in addition to the problem of supplying and mixing the oxygen and combustible gases, time is required for the various chemical reactions to take place.

There is but little chance for thoroughly mixing all gases in the combustion chamber, as the rapid rate with which the gases ascend prevents a thorough mixing, so that stratification of the gases results.

In proof of the above the author gives analyses of samples taken from the first-pass baffle opening of a boiler immediately under the first row of tubes.

These readings showed a carbon dioxide content of from 10.0 per cent along the walls to 17.5 per cent in the center. From these figures it can be appreciated that the chances for the ferrous material to change into the ferric state are very few. It was evident that there was an insufficient penetrative effect from the ventilated walls to take care of the wide furnace, and it is also noted that there was considerable excess air along the walls.

Numerous samples of coal ash and slag were analyzed and it was found that the slag on the furnace walls ran much higher in ferrous iron, by per cent, than did the slag on the tubes. In consequence of this the slag on the walls was much freer from the coarse, friable, infusible material than was the material on the tubes.

Numerous theories were advanced during this investigation as to the causes of slag formation on the tubes. Chief among these was the condensation of tarry vapors on the tubes, to which the flying particles could adhere and solidify.

Whether condensation of tar can actually occur is, however, subject to doubt in view of the facts pointed out by the author.

In the large number of tests made it was indicated that the slag deposit on the tubes was nearly proportional to the total amount of gas, and was not greatly affected by the rating. The amount of slag was affected by the temperatures in the furnace, however, for the hotter fires kept the slag in a more viscous state, which greatly increased the tendency for cinders and particles of ash to adhere.

In trying to prevent slag accumulation three methods were considered. Among these the injection of steam into the air supply was tried, but no decrease was noticed in the formation of slag on the tubes. Another method now being tried is that of intimately mixing air with the gases. The original boilers were set about 13 ft. from the grates. It was thought that by increasing the distance between the grates and boiler tubes the gases would have more opportunity to mix thoroughly. Also, since the total time of travel of the furnace gas is dependent upon the velocity and distance of gas travel, more time would be allowed for complete oxidation of the small particles. Consequently a boiler was set up 6 ft. higher than those originally installed.

Assuming that the rapidity with which the gas rises from the fuel bed is uniform, it is calculated that its velocity was about 18 ft. per sec. This is the lowest possible velocity that can be expected. The direction of gas travel is from the grate direct to the baffle opening, which was proportioned as 46 per cent of the grate surface.

Necessarily the velocity was twice as high under the baffle as it was leaving the fuel bed.

On this basis the time it took for particles to reach the tubes with the original installation would be 0.72 sec. This is very little time for oxidization to take place, unless it is of an explosive character. Further, by raising the boiler to 19 ft. this same time would be 1.05 sec., which is still a very short period.

This arrangement has not shown any great improvement in slag prevention and has the disadvantage of exposing more brickwork to high temperatures and to draft, with resulting greater infiltration of air through the setting.

Furnace construction undoubtedly has much to do with the external incrustation of the tubes with slag. The ratio of the exposed tube surface to the grate area was 1 to 1. This is very low and the lower the ratio, under set conditions of fuel and fuel bed, the higher will be the furnace temperature. It is apparent that the higher the furnace temperature, the greater will be the tendency for the ash to fuse and stick.

It has become common practice now to have the ratio of exposed tube surface to grate surface as high as 1.87 to 1, and it is seldom less than 1.2 to 1. By increasing this ratio the amount of heat radiated up and absorbed is very materially increased, with a consequent reduction in furnace temperature. This last item, namely, furnace construction, is a step in the right direction.

It is extremely fortunate that only a comparatively few coals give slag trouble to a serious degree. A great many coals have fusing temperatures so high that they give no trouble with ordinary furnace temperatures. Another class of coals have low fusing temperatures, but do not seem to have the tendency to be lifted from the fuel bed. But when a coal gives serious slag trouble, with the present knowledge of the art of burning coal, means must be provided for its mechanical removal. This, however, is not as serious a matter as it appears, for soot blowing in boiler plants is now recognized as a necessity, and apparatus for soot removal is now installed as regular boiler equipment. (*Power Plant Engineering*, vol. 26, no. 22, Nov. 15, 1922, pp. 1094–1098, 7 figs., *eA*)

Electric Steam Generators

Electric Steam Generator, E. M. Horstkotte. Description of an electric steam generator designed by the General Electric Co. It is stated that it requires power at the approximate rate of 1 kw-hr. for every 3 lb. of steam generated. The complete equipment consists of the shell with supporting feet, the electrodes, insulators, steam and water gages, safety valve, circulating pump and motor, and a panel on which is mounted the control equipment. The electrodes are of round iron and the electrical operation resembles somewhat that of a three-phase arc furnace.

Normally, the electrodes are submerged in the water, and the three-phase current passes through the water to the sides of the tank and to the neutral of the system, also from electrode to electrode. The steam is generated by current flowing through the water, which is of high resistance. The mechanical circulation of the water has been described, but some of the operating features arising from it are of sufficient interest to merit further consideration. One result is that the temperature of all the water in the system is practically uniform. If the steam pressure lowers owing to an increased demand, rapid steam generation, due to the high temperature of the water and the degree to which the electrodes are submerged, quickly brings the pressure up again.

Another operating feature is that since the water level is maintained by the adjustment of the throttle of the circulating pump, the energy consumption of the generator is not dependent on the operation of the feedwater pump. The supply of water in the hotwell is regulated by an automatic feedwater regulator. Furthermore, when it is desired to reduce the load, the generator does not have to be blown. The only energy losses in the circulating pump operation are the motor losses and the bearing-friction losses. Practically all the energy delivered to the pump impeller goes into heat in the water, therefore the loss from this source is small.

These electric steam generators have been designed for pressures ranging from 200 lb., maximum to 15 lb. minimum. Tentative layouts have also been made on generators of 3000 kw. capacity operating at 1 lb. pressure. These generators can be designed for any boiler pressure now being used, up to 50,000 kw. capacity and down to 250 to 300 kw. Below this lower limit generators of this type would probably not be as economical to build as some sort of immersion type using a metallic resistor.

One of the interesting features of operation of the electric steam generator is the interlocking of the various controls for purposes of safety. Suppose, for example, the circulating pump ceases to function, from voltage failure or other cause. The water in the electrode chamber simply drains into the hotwell, and since the electrodes are no longer submerged, no more steam is generated. On resumption of the pumping, since there is no hot metal surface in the electrode chamber, there is no danger of an explosion similar to that due to a hot crown sheet in a boiler. Also, when the water drains out there is no danger of burning any part of the electrode chamber, because when there is no water there is no heat generated. Too high a level of the water is prevented by an emergency overflow pipe of large diameter, whose top is some distance from the top of the electrode chamber.

There are instances where the electric steam generator might prove a valuable adjunct to the plant equipment either in utilizing excess electric power formerly wasted or in providing process steam directly where it is needed. An electric generator operates with only very little attention and therefore may be economically used under certain circumstances in preference to a steam generator.

This applies, in particular, to mills that purchase power on a maximum-demand basis. Suppose, for example, a factory contracts for 10,000 kw. maximum demand. It is possible that, owing to one cause or another, the load factor for the year may be as low as 75 per cent. In such a case 2500 kw-years, or 21,900,000 kw-hr., are being paid for but not used. By installing an electric steam generator to utilize this energy the fuel bills would be cut materially. Assuming a coal-fired boiler with an efficiency of 65 per cent and coal with 13,000 B.t.u. per lb., for every 4953 kw-hr. used in the generator one ton of coal would be saved, or 4421 tons per year. If oil-fired boilers are used, operating at 75 per cent efficiency and using oil weighing 8 lb. per gal. with 18,700 B.t.u. per lb., for every 32.9 kw-hr. there would be saved one gallon of oil, or 665,650 gal. per year. These figures are calculated on the basis that all the excess energy would be utilized. If only 75 per cent was so utilized, the savings is said to be still enough to more than justify the installation of a steam generator. (*Power*, vol. 56, no. 21, Nov. 21, 1922, pp. 795–797, 3 figs., *dA*)

In commenting on the progress of the electric boiler, an editorial in *Power* calls attention to the fact that there is installed or under construction in this country and in Canada about 200,000 kw. normal capacity of this kind of equipment. This is equivalent to the evaporation of 700,000 lb. of water per hr. from and at 212 deg. fahr.

While the size of this equipment varies, the average unit is large, and for 19 installations the average size of boiler is over 9000 kw. while the largest unit with a normal rating of 25,000 kw. has absorbed as high as 33,000 kw. (*Power*, vol. 56, no. 21, Nov. 21, 1922, pp. 811–812, editorial)

The Flash Evaporator. Description of an apparatus for producing distilled make-up water made by the Schutte-Koerting Co.

The particular feature of this type of evaporator is that evaporation takes place in a chamber containing no tubes. This is accomplished by circulating the raw water continuously through the closed heater operated by exhaust steam to a vacuum flash chamber or evaporator and then back to the heater. In this apparatus the vapor discharge line of the flash chamber may be connected to the main unit condenser or to a special "distiller condenser." In this way a vacuum is maintained such that the temperature of the raw water leaving the closed heater is considerably above that corresponding to the absolute pressure in the flash chamber. The result is that as the water enters the chamber a certain fraction of it flashes into vapor. This passes over to the condenser and enters the system as distilled make-up water.

The following advantages are claimed for the flash evaporator; Elimination of evaporator scale trouble; removal of air and other gases; automatic control of evaporator feed and evaporator blow-down; and high rate of heat transmission in the heater due to the absence of a steam film between the tubes and the surrounding water. (*Power*, vol. 56, no. 22, Nov. 28, 1922, pp. 834–835, 3 figs., *d*)

POWER TRANSMISSION

Wave Transmission of Power

Wave Transmission of Power. Description of the machinery and exposition of principles underlying the operation of the Constantinesco system of power transmission by waves generated in a liquid.

During the war this system was applied with great success in the so-called CC synchronizing gear for firing machine guns through aircraft propellers in such a manner as to avoid hitting the blades of the propeller. The apparatus proved to be so reliable that it was ultimately used for testing ammunition, it having been found that premature explosion and especially delayed ignition of ammunition powder was more liable to occur than irregularities in the operation of the gear. The patents in Great Britain and the Dominions are controlled by W. H. Dorman & Co., Ltd., who, among other things, have applied this method to the operation of hammer rock drills.

Notwithstanding the fact that until recently information available as to this process has been scarce and difficult to obtain, fairly complete particulars concerning it were given in Mechanical Engineering, vol. 42, June and November, 1920, pp. 359–360 and 633–634.

The present article, among other things, gives data on the operation of the Dorman wave-power-driven rock drill as compared with a compressed-air drill.

Different figures have been published setting forth the performance of the Dorman wave-power rock drill. They show some considerable variation, as might be expected, in view of the fact that the rate of drilling must naturally depend upon the precise degree of hardness of the rock and upon the exact condition of the drill steel as regards sharpness. The first-named factor is not constant from hole to hole even on the one piece of rock, while the latter is subject to progressive deterioriation during the drilling of a hole to an extent which reflects the hardness of the rock. We give below a set of comparative figures which we ourselves observed in the course of a test made in our presence. The exact rate of drilling depends, of course, upon the operator to a considerable extent. He has it, at least, within his power, if skilful, completely to upset the value of the figures obtained in a comparative test. On the other hand, a close observer can readily tell when the operator is not working the drill to its full capacity, for if he holds it back at any time he must make it good afterward by turning the feed handle for a time at above the average rate. During the tests to which the following figures relate one operator—an employee of Messrs. Dorman—was employed throughout. We saw no evidence of any undue reduction in the feed during the compressed air drill trial. On the contrary, we noticed that with both drills occasional jamming occurred as a result of the steel being fed into the rock at slightly too great a rate.

TEST RESULTS ON HARD GRAY CORNISH GRANITE

Drill	Diameter of steel, in.		Feed per min., in.	Volts	Amperes
Wave transmission...	$1^7/_8$		$7^1/_2$	410	37.5
Wave transmission...		light load		410	22.5
Compressed air......	$1^7/_8$		$4^1/_2$	410	48.5
Compressed air......		light load		410	18.0

On the basis of these figures it will be seen that the Dorman drill performed about 75 per cent more work in the same time than the compressed-air drill, and consumed in so doing about 25 per cent less power. When running with the drill out of action, the Dorman drill consumed 25 per cent more power. The figures for the Dorman drill include the energy required to supply the flushing water. In the case of the compressed-air plant the flushing water was supplied by a separate pump, the energy consumption of which was not measured. The compressed-air drill was of a modern type—we cannot obviously specify its design—and was supplied by an air compressor of equally modern form. The compressor was not unduly large. In fact, it was only just large enough to drive the drill, as was shown by the fact that the receiver pressure fell slightly—from 82 lb. to 75 lb. per sq. in.—when the drill was brought into full action. It will be understood that the electrical consumption figures represent the energy supplied to the motors driving the wave-power generator and the air compressor, respectively. The same instruments were used in both cases. (*The Engineer*, vol. 131, nos. 3187 and 3188, Oct. 27 and Nov. 3, 1922, pp. 444–445 and 466–468, 8 figs., *deA*)

In view of the novelty of the subject and comparative difficulty of securing the necessary information, the following list of U. S. patents and patent applications on wave transmission held by the British W. H. Dorman & Co., Ltd., may be of interest:

Patents

1,211,679/17	1,334,287/20	1,334,281/20	1,334,282/20
14,738/19	1,334,280/20	1,334,290/20	1,372,944/21
1,334,283/20	1,334,288/20	1,334,291/20	1,334,285/20
1,334,284/20	1,334,289/20	1,372,941/21	1,372,942/21
1,372,943/21	1,410,100/22	1,400,019/21	

Applications

495,221/21	495,222/21	415,861/20	415,119/20

This list is taken from a pamphlet printed for Mr. Walter Hadden, connected with W. H. Dorman & Co., in London, which gives, in addition to U. S. patents, patents issued in other countries including Great Britain.

PUMPS

Rotary Pump with Reduced Friction Losses

A New Type of Rotary Pump with Blades, A. Poitrineau. The general belief is that rotary pumps with blades are inefficient because of the excessive friction between the blade and the casing, rapid wear of parts, and excessive leakage.

The author considers (without, for the time being, going into the question as to how it can be done) the case of a rotary pump with blades where the blades do not come in actual contact with the

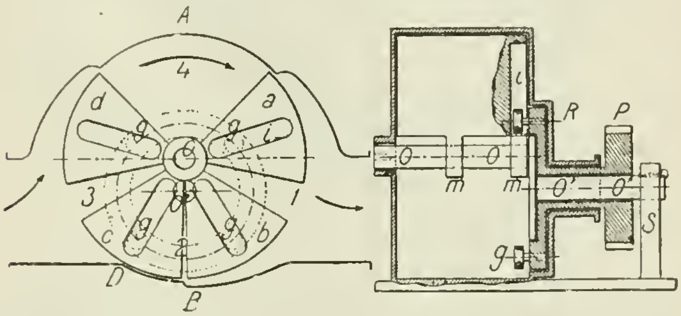

Fig. 8 Poitrineau Rotary Pump

casing. If this be so, friction between blades and casing will be eliminated but leakage increased; but this may not be very objectionable, as the author shows that in such a case the amount of leakage becomes of less and less importance as the velocity of the pump increases.

In the pump designed by the author the following four conditions have been satisfied: (1) There is no friction between the blades and the casing; (2) rubbing contact between parts is replaced by rolling contact, (3) high velocities of rotation have been secured; and (4) all liquids are admitted near the axis.

Fig. 8 shows a pump with four blades, a, b, c, d, rotating about an axis O in a cylindrical casing with one orifice for water admission and another for its exit. A wheel R, driven by pulley P, revolves around the shaft $O'O'$. This wheel carries four equidistant rollers g which travel within rectilinear guides in the blades (i in the section). The operation of this pump is similar to other blade pumps with an eccentric drum—with this essential difference, however, that the drum is here replaced by the roller-bearing wheel R. The wheel R in rotating at a constant velocity carries with it the rollers which roll in their respective races and push the blades at velocities varying with their distance from the axis. In other words, it is simply a quick-return mechanism of the first order but of multiplex type. The thickness of the blades is so proportioned that at an instant when the bisecting planes form with the faces of two consecutive blades a minimum angle, the two adjacent walls are in touch. An examination of Fig. 8 shows that the two blades b and c, now in contact, will separate during one-half of the revolution and then tend to come together again. This will easily explain the method of taking in and driving out the liquid. In the case of Fig. 8, at each revolution a volume of liquid is delivered equal to four

times the volume 4, or practically equal to the volume within the casing.

The author explains the balancing of the parts at high speeds and the method of making the blade. From the article it is not clear whether any such pumps have been actually built, and if so, in what sizes and what were the actual efficiencies of the apparatus. (*Arts et Métiers*, vol. 75, no. 24, Sept., 1922, pp. 260–264, 9 figs., *d*)

RAILROAD ENGINEERING

Rowan Locomotive Piston Packing

ROWAN LOCOMOTIVE PISTON PACKING. Description of a type of locomotive piston packing applied on several of the Irish railways. The piston ring as applied to locomotive pistons is shown in Fig. 9.

There are two casting rings *A,A* turned to the exact diameter

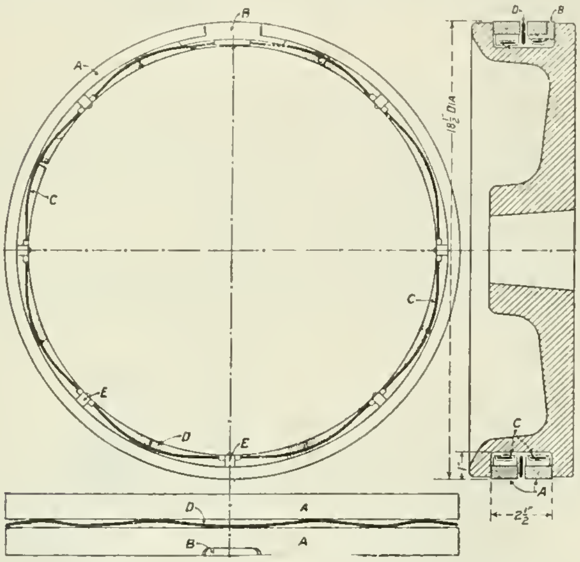

FIG. 9 ROWAN LOCOMOTIVE PISTON PACKING RINGS

of the cylinder, the split being covered by a steel spring *C* which consists of a hoop of steel of a diameter somewhat larger than the internal diameter of the ring. At intervals on the spring *C* there are a number of knuckles *E*. By forcing the hoop into the ring it is deflected from its circular form into a series of arcs—one between each pair of knuckles.

As shown by this the distinctive feature of this packing lies in the use of a separate spring to produce the proper expansion of each ring, with the addition of a third spring to keep the rings in steamtight contact with the outer side of the groove in the piston.

It is claimed that with this design each spring can be accurately adjusted for its particular function and that the pressure exerted by the rings against the cylinder walls does not exceed 2 lb. per sq. in. and is ordinarily about $1^1/_2$ lb. per sq. in., this being sufficient to insure steamtightness without causing excessive friction.

With superheated steam the piston springs are exposed to temperatures which draw the temper of ordinary spring steel. To meet this condition the manufacturers of the Rowan piston ring have developed an alloy having special heat-resisting and temper-retaining qualities which is being used in the manufacture of this locomotive piston packing. (*Railway Review*, vol. 71, no. 19, Nov. 4, 1922, pp. 615–616, 1 fig., *d*)

THE STREET LOCOMOTIVE STARTER. Description of a device the purpose of which is to give increased power to a locomotive at starting. Its function is different from that of the booster, as it is intended to assist the locomotive only when starting and is designed for use only at very low speeds. The starter consists essentially of a heavy cast-steel ratchet wheel driven by a steam cylinder. The piston of this cylinder is driven through its working or forward movement by steam pressure and through its return or backward movement by a spring. With the ratchet wheel goes a ratchet which can engage it and is carried by a pair of lever arms operated by the piston rod. When the machine is idle and during the return stroke of the piston this ratchet is held out of contact with the ratchet wheel. When steam pressure is admitted to the cylinder the ratchet is forced down into contact with the ratchet wheel and holds it there as long as the pressure exerted by the steam is greater than that of the springs which hold the ratchet up. The steam pressure and the strength of the springs are so proportioned that the ratchet is forced down before there is any forward movement of the main piston and lifted before its return movement. This arrangement eliminates any dragging of the ratchet over the ratchet wheel and the unnecessary wear and noise which would result if this were permitted.

The control mechanism consists of a 1-in. steam line leading from the dome of the locomotive to the cylinder of the starter with a throttle at the dome and a flexible joint at the cylinder. The throttle is opened and closed through the medium of a $^1/_4$-in. copper pipe leading from the throttle to a push button in the cap. When the push button is held down the machine will run, and when it is released it will stop.

It is important that all piping and the cylinders be free of water in order that the machine may respond instantly when action is demanded. To insure this the starter has an automatic drain valve at the lowest point of the cylinder which remains open at all times when there is a pressure of less than 10 lb. in the cylinder, and closes automatically under any greater pressure.

In the original article is shown a machine designed for application to a locomotive trailing truck having wheels 43 in. in diameter and carrying a weight of 52,500 lb.; the tractive force exerted at the rim of the wheel with a $10^1/_2$-in. cylinder and 200 lb. boiler pressure would be 12,900 lb. A smaller type is also built.

It is claimed that in passenger service the starter will eliminate starting shocks resulting from taking up slack. In freight service it will eliminate the need for taking up slack in order to get a train under way, and in so doing will reduce break-in-two's and draft-gear and coupler failures. (*Railway Age*, vol. 73, no. 19, Nov. 4, 1922, pp. 858–859, 1 fig., and *Railway Review*, vol. 71, no. 19, Nov. 4, 1922, pp. 613–615, 3 figs., *d*)

REFRIGERATION

Experiments on Ice Making—Supercooled Water

METHODS OF FREEZING RAW WATER, Halbert Paul Hill. Description of what appears to be a novel method of ice manufacture in which an attempt is made to make a practically continuous cake of ice from which pieces may be cut off as desired. The method is based on the use of supercooled water. It is known that strongly agitated water may be cooled below its theoretical freezing temperature without solidifying. In tests made by the author, water strongly agitated and surrounded by a 14-deg. fahr. brine was reduced to 26.8 deg. fahr. before it flashed and ice crystals were formed. In other experiments water was not agitated but covered with a film of oil and a temperature of 25 deg. fahr. was reached without crystals forming. A piece of ice was dropped into the water and crystals slowly formed. The peculiar thing in the formation of these crystals is that they formed in laminated sheets. After proving that water could be supercooled, a plant was built with the idea in view that if ice crystals could be made in sufficient quantities and the ice cans filled with a concentrate of ice crystals and water at 32 deg. fahr., a marked step in the development of a more commercial method of manufacturing ice would be obtained. Notwithstanding all efforts made it was found impossible to use this plant on a commercial scale as the equipment would work only a few minutes, when the cooler would freeze up. This happened even when high back pressures from 42 up to 100 lb. per sq. in. were used. The apparatus, it seems, was provided with screens of 200 mesh in the bottom of the tank to prevent the crystals from being carried to the cooler. As a matter of fact, however, the crystal formations break up into such minute particles that they readily pass through eight to ten thicknesses of 200-mesh screen reinforced with cheesecloth, and these minute crystals once in the cooler cause the flashing.

A device was then developed for separating crystals by gravity. After this separator was connected between the tank and the cooler, supercooled water could be made and maintained for an indefinite period at temperatures below 32 deg. fahr, and it was

believed that by introducing the supercooled water into a refrigerated can or receptacle the water coming in contact with the refrigerated surface would deposit laminations of ice thereon, thus removing the heat through water instead of through ice. Numerous experiments were made but without satisfactory results on a commercial scale at first. Thirty-seven forms of cans of various types and shapes were made. In all of these absolutely clear ice was made but in no case was it possible to deposit crystals that would adhere to the refrigerated surface or to the ice formed. This led to further experiments to determine the relation between supercooled water and ice crystals.

In the course of these experiments another means was employed in the hope of solving the problem. A large cast-steel ammonia-jacketed can, weighing 7000 lb., was made in two sections, machined inside and bolted together. This can was 6 ft. 9 in. long and the ammonia-jacketed section 6 ft. long. It was open at the ends and the front end was provided with a cover and an inlet and outlet; in the center an agitator was provided. The idea was to admit supercooled water into the can through the top inlet, agitate it in the can, and discharge it from the lower outlet. The object of the agitator was to mix the supercooled water and crystals so that the entire mass would be of one temperature and the crystals would be deposited on the refrigerated surface of the can and thus make ice. Means were provided to lubricate the inner surface of the can, the intention being to make ice continuously, allow it to slide out of the can as made, and then saw it off into standard lengths. The system was not a success.

Experiments are now being conducted in an attempt to make ice in an open tank, separate the crystals in the water by a centrifugal separator and then press them into a cake by means of hydraulic pressure. The crystals made from supercooled water are so minute that they can hardly be distinguished from water when in a glass, being so clear. By subjecting them to pressure, however, they can be compacted so that solid ice can be made.

In the course of these tests an endeavor was made to stabilize the crystallization point by catalytic action. Various acids and alkalies were added to the water with a view of decreasing the freezing point and with the hope of discovering some means whereby the crystal formation would be retarded. Certain dyes were used, as well as starch, glycerine, and other chemicals. A thorough study of the crystal formation of sugar, salt, glycerine, and various chemicals was made and a number of very interesting experiments were conducted with electrical apparatus. Glass containers were made surrounded by coils of wire through which both alternating and direct current were applied with a view to stimulating or directing crystallization by magnetic lines of force.

It would appear, therefore, that while no commercial result has yet been obtained from the work of the writer, some facts of considerable scientific interest have been established. (*Refrigerating Engineering*, vol. 9, no. 4, Oct., 1922, pp. 127–131 and discussion, pp. 131–132, 11 figs., *eA*)

Thermodynamics of Ammonia Compression, W. H. Motz. Brief discussion of general thermodynamic principles followed by a derivation of the various formulas used in the design of ammonia compressors.

For the constant k in the formula for mean effective pressure where ammonia is compressed adiabatically (ratio of specific heats) the author recommends a value of 1.31. Some of the formulas are accompanied by examples and a number of curves and tables are given, among them being a table for the mean effective pressures of ammonia and curves for mean effective pressures for various suction and discharge pressures. Formulas for the mean effective pressure with and without clearance are given, and the author points out that the mean effective pressure with clearance is equivalent to the mean effective pressure without, multiplied by the clearance factor, or the volumetric efficiency due to clearance. The effective displacement of the compressor cylinder with clearance is reduced in direct proportion to the volumetric efficiency due to clearance, and the mean effective pressure of the cylinder with clearance is reduced in the same proportion. This indicates, theoretically, that the clearance does not effect the work requirements for a given amount of refrigeration. In passing, the author calls attention to the formulas and tables given by Carl J. Jefferson in an article entitled Mean Effective Pressure of Ammonia Compressors, in the Sept. 18, 1917, issue of *Power*. He claims that the formula given therein is incorrect (because it apparently assumes a 100 per cent condition the whole distance), as is also Mr. Jefferson's table of mean effective pressures with varying clearances, suction pressures, and condenser pressures. (*Refrigerating Engineering*, vol. 9, no. 4, Oct., 1922, pp. 119–124, 6 figs. and discussion pp. 124–125 and 132–133, 2 figs., *gt*)

SPECIAL PROCESSES

Dust Separation by Gravity

Gravity Method of Dust Separation, Dr. Karl Wiest. The gravity method of dust separation is still used in many instances because it is the cheapest to employ under certain conditions, and when properly applied gives excellent results. The method of operation of gravity-type dust-separation plants rests on the fact that when the velocity of the gas in which the dust is held in suspension is decreased the dust particles have time to settle out because of their higher specific gravity. The author shows that both in stationary and in moving air each particle of dust has a certain velocity of fall peculiar to itself, and establishes a law to the effect that *the efficiency of a dust-separation chamber is a function of its floor area*, while the height must be only great enough to prevent the flowing gases from picking up and carrying off dust from the floor. If this is so, the general opinion as to the importance in a dust chamber of sufficient *volume* would appear to be incorrect. This is of considerable importance in connection with the use of standpipes forming part of the usual air-cleaning equipment in blast-furnace plants.

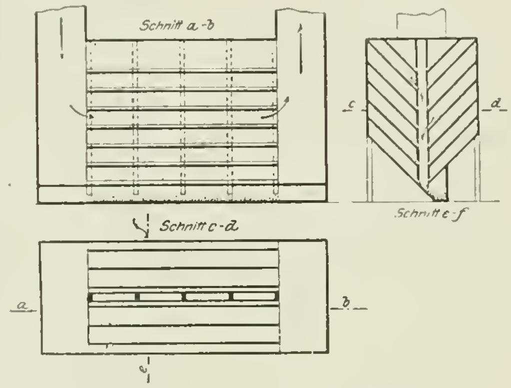

Fig. 10 Dust-Separating Chamber with Multiple Partitions between Floor and Ceiling

In order to test out the correctness of the above rule, in a certain dust-separating chamber of rectangular cross-section a false floor was built in at half the height of the chamber over one-half of its width. If the law as to the importance of the floor area of the chamber in governing the amount of dust separated out from the air be correct, there should be deposited on each of the two halves of the subdivided chamber approximately as much dust as on the floor of the undivided half. The test proved that this is so.

Furthermore, the dust chamber with the multiple subdivision in the vertical direction as shown in Fig. 10 (patented by the author) gave a dust separation many times greater than that obtained in a simple chamber. Among other things, the author shows a smokestack where steplike baffles have been built in to modify the free flow of the gases and to force them to deposit the heavier particles of dust on these baffles.

The effect of velocity of fall on the separating out of dust particles may be utilized in the case of smokestacks delivering their gases into the open air, where, for some reason or other, excessive dust may be objectionable. A smokestack in itself is not an apparatus for the dust separation, but it may help to protect from dust the surroundings of the plant. If a particle of dust having a velocity of fall k leaves a smokestack of the height H and is immediately picked up by a wind velocity w, it is carried away for a period of time necessary to have it fall through a height H. Its distance of flight will therefore be $f = Hw/k$. The higher the smokestack

the greater the wind velocity, and the smaller k the greater will be the distance to which the particle of dust is carried. If the wind is very slight the gases, and with them the dust particles, do not spread horizontally immediately upon leaving the mouth of the smokestack, but rise more or less. If, however, the smokestack has built into it a dust-separating chamber which gives a certain velocity k', no dust particles can leave the smokestack which have a velocity of fall greater than k', and therefore the minimum distance of flight will be $f_{\text{min.}} = 3H/k'$, the wind velocity being here assumed as 3 meters per second. As a result no dust can fall within the radius of $f_{\text{min.}}$. (*Stahl und Eisen,* vol. 42, no. 44, Nov. 2, 1922, pp. 1650–1653, 4 figs., *de*)

Reinforced-Concrete Pipe Made by Centrifugal Process. Description of centrifugally cast concrete pipe made by the Lock Joint Pipe Co. at Ampere, N. J., and Denver, Colo. The machine used does not essentially differ from similar machinery in the Hume process (described in Mechanical Engineering, July, 1922, pp. 474–475) and in some German processes. The whirling form is of wrought iron in take-down construction and is set up around the reinforcement cage so arranged that the cast-iron joints at the end of the cage are flush with the circumference of the form. The grooves or sheaves of the form are then engaged by an endless steel cable hanging from the frame and give the form its motion.

In one respect the machine is different from the Hume, viz., in that it uses a charging bucket consisting of a longitudinally placed cylinder with a slot a few inches wide along its elements. It is completely filled with concrete through the slot and then moved longitudinally on tracks into the center of the whirling form. Once the charging bucket is inside, the form is started to whirl and the charging bucket is slowly turned over so that it discharges its concrete content uniformly along the inside of the form where it is immediately thrown outward by centrifugal force. The size of this charging bucket is so proportioned as to give the proper concrete content to form a shell of a required thickness.

After the form has been whirling for about five minutes there is inserted into the center a pan resting clear of the form at either end and projecting from the center of the form. It is used as a guide for brushes, manipulated by the attendant, which clean the interior of the pipe and collect the excess water which clings to the whirling surface. It is said that in a pipe 20 in. in diameter, $2^1/_2$ in. shell thickness, and 12 ft. long with a concrete that would be considered of normal working mortar plasticity, a full wheelbarrow load of cement, colored water and laitance is drawn off.

The concrete from which the pipe is made is a mortar rather than concrete, as it is a one-half mixture of portland cement and ordinary good, clean building sand. The finished pipe presents a remarkably uniform surface. So far no tests have been made as to their strength, but they are being used for pressures up to 50 lb. per sq. in. for the 20-in. pipe and have resisted pressures up to 200 lb. per sq. in. (*Engineering News-Record,* vol. 89, no. 80, Nov. 16, 1922, pp. 829–830, 4 figs., *d*)

STEAM ENGINEERING (See Power Plants)

THERMODYNAMICS (See Refrigeration)

VARIA

Sculpture by Camera. In the December, 1922, issue of Mechanical Engineering (p. 843) a method of portrait sculpture by the aid of photography was described by W. F. Engelmann of Chicago. It is now stated that Howard M. Edmonds, a graduate of the Massachusetts Institute of Technology, has developed another method for accomplishing the same result. In this method a lantern projector popularly known as a magic lantern throws on the face of the sitter a series of closely spaced lines. These lines projected on a screen are fine, straight parallel lines, but when thrown on the face of the subject and viewed from a certain angle they appear curved and follow the contours of the face. A photograph is then taken of the subject with these lines projected on the face with a strong light, and the negative shows the many curved lines on the face. A positive is then made from a negative and given to the operator of the carving or sculpturing machine.

Connected with the machine is a drill which can be made to rotate and also to move in a straight line and scratch thin lines on the marble or such material as may be chosen. The operator by the use of levers and handles can control the drill and make it begin and end at any point, and can also regulate the depth of cut. To secure a likeness of the model the operator manipulates a pointer which is connected to the drill so as to follow the curved lines on the photograph. As the pointer traces out the lines on the photograph the drill moves up and down, making cuts of various depth as it moves along in its straight-line path. As the lines curve in on the photograph the drill cuts deeper and as they curve out it cuts shallower, and in this way the varying contours of the subject's face are reproduced in marble. In practice it is found that polishing and a certain amount of hand carving of the hair

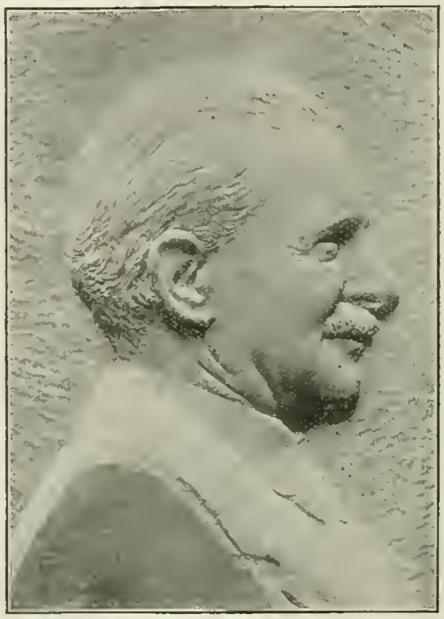

Fig. 11 A Bas-Relief Made by the Edmonds Photographic Process

is necessary, but otherwise the machine does the entire work of carving, and by eliminating the necessity of a skilled sculptor brings the sculptured portrait within the province of persons of moderate means. (*The Tech Engineering News,* vol. 3, no. 5, Nov., 1922, pp. 148–149, 1 fig., *d*)

German Export Policy. The more important of the German oil-engine manufacturers maintain a complete sales organization covering the entire world. For example, one prominent builder has over 400 salesmen in South America, Egypt, India, China, etc. These salesmen are not mere brokers but direct representatives, selling the builder's product and devoting their whole time to this business. If the engine sales are insufficient to give the salesmen a profitable business, the engine builder takes on some other line of machinery that can be readily sold in the territory under question. This increases the profits of the representatives and ties him still closer to the engine builder. The engines for export are finished according to the demand of the country into which they go. Local desires as to painting, extra parts, crating, etc., are complied with. In making export prices on account of exchange conditions the factory cost has but slight influence and the quoted price depends on the price prevailing in the country to which the engine is going. The extent of the German foreign trade in oil engines may be judged by the fact that in one South American country a German builder maintains a repair shop having a payroll of 40 men. (*Power,* vol. 56, no. 23, Dec. 5, 1922, pp. 878–879, *g*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Forty-Third Annual Meeting of the A.S.M.E.

Noteworthy Week Comprising Twenty-four Sessions Dealing with Professional Subjects, Economics, and Industrial Education and Training—Local Sections' Conference a Prominent Feature

THE FORTY-THIRD Annual Meeting of The American Society of Mechanical Engineers was notable for its well-balanced, diversified program with splendid papers and enthusiastic discussion. The four days of the meeting, December 4 through 7, 1922, formed a very intense period, however, for during that time there were twenty-four sessions, fifty-three committee meetings, and four social events. This was followed by the National Exposition of Power and Mechanical Engineering which opened on Thursday, December 7, at one o'clock at the Grand Central Palace. It was a remarkable week and the 1836 who registered left the meeting with a feeling of having attended a very successful affair.

The presidential address of Dean Dexter S. Kimball attracted wide attention and gave mighty inspiration in its challenge to the engineer to assume his proper responsibility in maintaining and developing civilization. He was given an ovation at its presentation on Monday evening of the meeting. The address appears in full as the leading article of this issue.

Perhaps the most interesting session of the meeting was that on Engineering and Economics held on Wednesday evening, December 6. President Dexter S. Kimball presided over a program arranged jointly by the A.S.M.E. Management Division and the American Economic Association. Papers were presented by Dr. W. C. Mitchell on Making Goods and Making Money, and by E. M. Herr on The Human Problem in Industry; and H. R. Seager, E. F. DuBrul, F. J. Miller, and J. L. Harrington contributed to the discussion. These addresses with the discussion appear on other pages of this issue.

The Council met on Monday to transact routine business, and on Friday to install the new officers and consider questions arising from the proceedings of the business meeting. The outgoing President, Dean Dexter S. Kimball, was presented with a gavel, and the custom was inaugurated of also giving the incoming President this symbol of his authority. John Lyle Harrington was formally introduced as President; as were the new Vice-Presidents, W. S. Finlay, Jr., W. H. Kenerson, E. F. Scott, and H. H. Vaughn; and Managers, A. G. Christie, J. H. Herron, and R. V. Wright.

JOHN LYLE HARRINGTON — PRESIDENT, 1923
THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS

This Annual Meeting was also the scene of a very remarkable conference of Local Sections Delegates which lasted throughout the week. On Monday the delegates met all day to talk over Local Sections problems, breaking the gathering, however, for luncheon with the Council, at which a number of inspiring four-minute addresses were delivered by the officers and chairmen of standing committees. During the rest of the week the Local Sections Delegates met with the various Standing Committees of the Society for the discussion of national Society problems, and on Friday they attended the Council meeting. In the afternoon the Council attended the final meeting of the Local Sections Delegates. As a result of this week-long conference the members of the Society from afar learned of the inspiring importance of the Society's activities. A more complete account of the transactions of the Council and the deliberations of the conference of Local Sections Delegates appeared in the December 22 issue of *A.S.M.E. News*.

Business Meeting

On Monday afternoon, December 6, the annual business session was held. Its feature was the presentation of the report of Calvin W. Rice Secretary of the A.S.M.E., on his recent trip to South America. This appears in its complete form on page 72 of this issue of MECHANICAL ENGINEERING. Mr. Rice preceded this report by his customary summary of the work of the Standing Committees of the Society. The formal report of the Tellers on the ballot for the new Constitution and Code of Ethics was read. The following selection of the Nominating Committee by the Conference of Local Sections Delegates was approved: Charles L. Newcomb, Holyoke, Mass.; A. E. Allen, New York City; William H. Kavanaugh, Philadelphia; W. T. Magruder, Columbus; W. L. Abbott, Chicago; Louis Bendit, Kansas City; Sam H. Graf, Corvallis, Ore.; and alternates, L. D. Burlingame, Providence; S. H. Libby, New York City; H. S. King, Atlanta; C. W. Bennett, Columbus; William M. White, Milwaukee; L. D. Crain, Ft. Collins, Colo.; R. D. Hoyt, Portland, Ore. Announcement was made of the final approval of three parts of the work of the Power Test Codes Committee: The General Instructions, Code on Definitions and Values, and Code for Reciprocating Steam Engines. The following reports of the Research Committee were also presented for final approval: Standards on Malleable Iron Screw Fittings, Gears and Pinions for Electric Service, Gray Iron Industrial Spur Gears, Specifications for Steel Castings for Gears, Specifications for Brass and Bronze for Gears, and Specifications for Forged and Rolled Steels for Gears.

In presenting life membership to Major Fred J. Miller, resolutions of thanks from the Council were read which expressed an appreciation of Major Miller's service as president and as advisor and servant under all circumstances, not the least of which was his assumption of the burden of the secretaryship while Mr. Rice was in South America.

Life membership in the Society was also presented to Prof. R. C. H. Heck for a paper on Steam Formulas which was adjudged by the Committee on Awards and Prizes as the best one appearing in the 1920 volume of Transactions. The Junior prizes were awarded to R. H. Heilman of Pittsburgh for his paper on Heat Losses from Bare and Covered Wrought-Iron Pipe at Temperatures up to 800 Deg. Fahr., and to F. L. Kallam of Los Angeles, Cal., for his paper on The Investigation of the Thermal Conductivity of Liquids.

E. S. Carman, Junior Past-President and Chairman of the A.S.M.E. delegation to the American Engineering Council, emphasized the fact that the organization of national, state, and local societies composing The Federated American Engineering Societies is concerned more particularly with those engineering activities that are of great civic import.

L. W. Wallace, Executive Secretary of the Federation, gave a convincing report of the activities of the Federation.

Mr. Wallace called attention to the fact that in the two industrial reports which have been issued by the F.A.E.S., Herbert Hoover has written the introduction to the one on Waste in Industry and President Harding the one to the report on the Twelve-Hour

Shift in Industry. He spoke of the coöperation of the Federation with the Department of Commerce in standardization work and in adjusting the relations of the Federal Government with contractors; also of their coöperation with the Post Office Department in organizing a division for the handling of materials. Certainly the Federation has been influential in presenting certain legislative measures; and in the matter of a topographical map of the United States they have had introduced into Congress a law which will make possible the completion of this necessary map in twenty-five years instead of the one hundred years it will take at the present rate.

Following Mr. Wallace, Rudolph P. Miller gave a report on the National Board of Jurisdictional Awards in the Building Industry. This Board has been meeting on an average of four times a year and to date has rendered about 38 decisions, many or all of which have been instrumental in the settlement of industrial disputes before they have actually occurred. He urged that engineers everywhere give their support to this Board, showing that untold money may be saved for the people of this country by the elimination of the labor disputes over which the Board arbitrates. A review of the activities of this Board will be found on page 75.

Student Session

On Wednesday afternoon, December 6, Dr. William H. Kenerson presided over a gathering of representatives of Student Branches at which a number of problems relating to the activities of the Branches and their relation to the Society were given careful consideration. Addresses were made by Edwin S. Carman, Past-President, John Lyle Harrington, President-Elect; John Younger, and Calvin W. Rice. Representatives were present from the following colleges:

Armour Institute of Technology	Massachusetts Institute of Technology
Brown University	Michigan Agricultural College
Bucknell University	University of Michigan
California Institute of Technology	New York University
Carnegie Institute of Technology	North Carolina State College
Case School of Applied Science	Ohio State University
College of the City of New York	Oregon Agricultural College
University of Cincinnati	Pennsylvania State College
Cornell University	Polytechnic Institute of Brooklyn
Drexel Institute	Purdue University
Georgia School of Technology	Rensselaer Polytechnic Institute
Johns Hopkins University	Rutgers College
University of Kansas	Stevens Institute of Technology
University of Kentucky	Agri. and Mech. College of Texas
Lafayette College	Tufts College
Lehigh University	Virginia Polytechnic Institute
Lowell Textile School	Worcester Polytechnic Institute
University of Maine	Yale University

Social Events and Excursions

The meeting furnished its usual quota of valuable opportunities for good-fellowship. Although the President's Reception, usually held on Tuesday evening, was held this year on Monday, it was exceedingly well attended and an enjoyable evening resulted. The informal dinner and smoker on Tuesday evening gave the desired opportunity for the men to get together, and on Wednesday afternoon the ladies served tea. The dinner dance Thursday night was a success from every point of view.

Throughout the week an enthusiastic and capable ladies, committee was in attendance at the building and large groups of visitors were taken to the Museum of Natural History, to a private gallery of modern American paintings, to inspect the *Pictorial Review* building, the Hecksher Foundation and the Museum of the American Indian, and to a Fashion Show at Wanamaker's, where tea was served.

The more technical excursions included visits to the Hell Gate Station of the United Electric Light and Power Company, the Broadcasting Station WEAF of the American Telephone & Telegraph Company, one of the automatic exchanges of the New York Telephone Company, and the plant of the Wheeler Condenser Company at Carteret, N. J. Large groups visited the McGraw-Hill building for luncheon on Thursday, and the Battleship *Maryland* at the Brooklyn Navy Yard on Friday. A very interesting demonstration of the Christie amphibious gun mount was held on Tuesday afternoon, when this new device traveled over smooth roads on wheels, over broken country on its caterpillar tread, and then propelled itself across the Hudson.

Refrigeration Session

THE FIRST technical session of the meeting was held jointly with the American Society of Refrigerating Engineers, on Monday afternoon, December 4. Harry Sloan, President of the A.S.R.E., presided over a program of two papers. In the first paper, on the Design of Cooling Towers, C. S. Robinson[1] the author established a general principle applicable to cooling-tower design and derived equations for the use of the design. Extended discussion as to the practicability of the paper was submitted by Barton H. Coffey,[2] L. A. Phillips[3] and W. S. Grosvenor.[4] This paper will appear in abstract with the discussion in a later issue of Mechanical Engineering.

The second paper, by Percy Nicholls,[5] on the Economic Thickness of Insulation in Refrigerating Field, appeared in the December issue of *Refrigerating Engineering.* In this paper the author defines economic thickness for refrigeration as that which will reduce to a minimum the sum of the expenses due to heat passed through the insulation plus the expenses of prevention. The author discusses the factors entering into this definition, proposes a formula for determining the economic thickness of insulation, and points out some of its applications. In his conclusion Mr. Nicholls states that it has not been his purpose to recommend definite thickness but rather to establish a standard of reference and set out a basis of argument on which the figuring of thickness may be done. Neither will it be worth while to attempt in most cases to introduce refinements in calculation since corresponding close values for the various constants cannot often be predicted. Fuel prices in the future may be different and the efficiency of operation will depend on how the plant is run. It is, however, advisable to have an agreed standard method of computation to refer to in case of dispute, and on which to base practical rules, and if such agreement can be expressed as a definite formula, then the problem is reduced to fixing the values of the various symbols.

In the discussion Prof. A. J. Wood[6] stated the advantage of plotting "cost-thickness" curves. For ease in simplifying calculations, Professor Wood suggested combining the factors of interest, depreciation, maintenance, and taxes. He also suggested a chart to take care of surface effect and conduction of the structure independent of the insulation and to provide for that part of the year in which there are heat losses. He agreed with the author of the paper that the practical economic thickness is not an exact thickness.

C. H. Herter[7] pointed out the difficulty of evaluating some of the factors in Mr. Nicholls' formula and suggested some simple rules. If the average plant where the cost per ton of refrigeration amounts to about $2.50, he suggested the provision of 1 in. of pure cork board, or its equivalent, for every 15 deg. fahr. maximum air to air temperature difference. Where refrigeration is very cheap, allow 1 in. per 20 deg. maximum difference, and where refrigeration is expensive allow 1 in. for each 10 deg. maximum difference. He also suggested that for 1 sq. ft. of insulation it is proper to pay up to one-fifth or one-fourth of the total cost per ton of refrigeration. J. B. Starr[8] emphasized the need for consideration of upkeep as a factor in cost of installation.

Management Session

THE MANAGEMENT Session, held Tuesday morning, December 5, furnished a further opportunity for a discussion of the paper by L. P. Alford[9] on Ten Years' Progress in Management which had been discussed previously before a number of Local Sections during Management week, October 16–21. R. A. Wentworth, Chairman of the Management Division, presided over this discussion as well as over the discussion of the paper by Wallace

[1] Prof. Mass. Inst. Technology, Cambridge, Mass.
[2] Chief engr., The Cooling Tower Co., New York. Mem. Am.Soc.M.E.
[3] Treasurer, Cooling Tower Co., New York.
[4] Consulting chemist, New York.
[5] Research Laboratories, Amer. Soc. of Heating & Vent. Engrs., Bureau of Mines, Pittsburgh, Pa.
[6] Head Dept. M. E., Pennsylvania State College, State College, Pa. Mem. Am.Soc.M.E.
[7] Refrigerating Engr., Brunswick-Kroeschell Co., New York. Assoc-Mem. Am.Soc.M.E.
[8] President, Starr Engrg. Co., New York. Mem. Am.Soc.M.E.
[9] Editor *Management Engineering*, New York City. Mem. Am.Soc.M.E.

Clark on Relieving Industry of Burden, and the presentation of Progress Reports by the Committees on Standards for Graphics and Standardization of Terminology.

In introducing the discussion on Mr. Alford's paper, Fred J. Miller[1] expressed the thought that the most important progress in the ten-year period cannot be measured nor weighed as it is manifested mainly in the changed attitude of mind shown in the installation of management methods by the promotion of coöperation instead of the arousing of opposition and antagonism.

Dr. H. S. Person[2] stated as his opinion that the real measure of progress in management would be an analysis of the existence of the combination of the various management mechanisms listed in the report, which he thought to be impossible at present. He also thought that the greatest measure of advance in management, a more or less intangible but very real thing, is a new point of view, a new method of approach by management.

J. P. Jordan[3] combated the idea that cost control is a mechanism and emphasized that it is an absolutely indispensable organ of enlightened management. He decried the fact that management had failed to recognize the importance of cost control.

Dean Dexter S. Kimball[4] told of his experience in establishing a course of instruction for the fundamentals of management which he believed will be much more clearly understood during the coming years.

Dean R. L. Sackett[5] pointed out that the advance in management has been accompanied by the development of administrative engineering courses which are drawing the attention of students to the humanistic side of industrial engineering.

David B. Rushmore[6] emphasized the need for a true definition of management. He also spoke of the need for developing executives along fundamental lines as a real constructive work for industry.

L. W. Wallace[7] expressed the hope that during the next ten years management would become more informed as to the fundamental economics involved so that they can be more intelligently placed before labor and the public.

The paper by Wallace Clark[8] on Relieving Industry of Burden appeared in the December issue of Mechanical Engineering. In his discussion Dr. Person expressed the feeling that it is important that the problem of relieving industry of burden be treated from the social point of view, which must consider the internal forces that impinge upon the individual plant and against which the management is sometimes almost helpless unless they may be modified by concerted effort. Dr. Person pointed to the joint session with the economists at this Annual Meeting as a hopeful sign that the engineer is attempting to broaden his viewpoint.

Joseph E. Pogue[9] defined the major problem for the management engineer as the formulation of an industrial policy which will require technical proficiency and economic insight involving not only a coördination and control of the internal components of the industrial units but also a synchronization of this unit with the industry at large. The big job for the future is to learn how to explore and control the industrial interstices—the inter-department, inter-company, and inter-industry spaces—which now, unmeasured and neglected, cause the major inefficiencies in our industrial system.

Fred J. Miller emphasized the importance of perfecting administrative methods first and spoke especially about the reduction of inventories by reducing manufacturing time, one of the points stressed in Mr. Clark's paper. The reduction of manufacturing time can be brought about by proper planning and routing, and by entire coöperation on the part of all individuals in the plant.

John Younger,[10] speaking from the point of view of the manufacturer, emphasized the importance of external industrial conditions effecting idleness in a specific plant.

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[3] Con. Indust. Engr., New York City. Mem. Am.Soc.M.E.
[4] Dean School Engrg., Cornell University, Ithaca, N. Y. Mem. Am. Soc.M.E.
[5] Dean of Engineering, Penn. State College, State College, Pa.
[6] Cons. Engr. Gen. Elec. Co., Schenectady, N. Y. Mem. Am.Soc.M.E.
[7] Executive Secy., The Federated Amer. Engrg. Soc., Washington, D. C. Mem. Am.Soc.M.E.
[8] Industrial Engr., New York City. Mem. Am.Soc.M.E.
[9] Const. Engr. New York City.
[10] Standard Welding Co., Cleveland, O. Mem. Am.Soc.M.E.

L. W. Wallace stressed the responsibility of manufacturers to secure facts as to the need for a given commodity before money is invested in factories to manufacture this commodity.

John J. Swan,[1] representing the A.S.M.E. on the Joint Committee on Standards for Graphics, presented a progress report. The Committee has had a fairly complete bibliography prepared and a start has been made in the preparation of definitions and terminology and the presentation of chart forms. A questionnaire has been sent out to those using graphics and a great deal of valuable material has been received.

F. E. Town,[2] Chairman of the Joint Committee on Management Terminology, presented a progress report for this Committee in which was included a classification of management literature in accordance with the Dewey Decimal System. The general subject of classification was given consideration and it was the consensus of opinion that classification procedure should be inaugurated and changed as occasion warrants.

Session on Ash Handling

THE MATERIALS Handling Division arranged the program for the Session on Ash Handling on Tuesday, December 5, over which H. V. Coes, Chairman of the Division, presided. The program consisted of a paper by John Hunter and Alfred Cotton which described systems of ash handling for marine and stationary work. The discussion presented some added material about ash-handling methods which was of particular importance as an expression of the point of view of operating engineers. An abstract of the paper with an account of the discussion will appear in the February issue of Mechanical Engineering.

Machine Shop Session

FIVE papers were presented at the Machine Shop Session on Tuesday, December 5, at which F. O. Hoagland, Chairman of the Machine Shop Division, presided. The paper by F. E. Cardullo[3] describing a new system of Helical Involute Gearing for Use in Metal Planers appeared in abstract in the December issue of Mechanical Engineering. In the discussion of this paper F. K. Hendrickson[4] agreed with Mr. Cardullo as to the unquestionable need of helical gears for planer drives with a consequent reduction in chatter marks and machine vibration. Mr. Hendrickson also spoke of the advantage of the helical driving gear in reducing the tendency to lift when heavy cuts are being taken. Charles Meier[5] expressed the opinion that Mr. Cardullo's form of gearing increased the friction losses and end thrust. He was also of the opinion that greater accuracy may be required in mounting this system of gearing. G. M. Eaton[6] spoke of his experience with helical gears on railway work, telling especially of one gear that after 60,000 miles of operation was superior to a spur gear, although the drive possessed less efficiency.

Mr. Estabrook's paper on Testing Involute Spur Gears appears in abstract in this issue of Mechanical Engineering and the discussion on it follows thereafter.

The paper on Spherical Gears by Charles H. Logue appeared in full in the November issue of Mechanical Engineering. There was no discussion on this paper.

The remaining papers were by Walter Ferris,[7] on Application of Hydraulic Transmission Variable Speed Drive to Machine Tools and Manufacturing Processes, and by Fred A. Parsons[8] on the Power Required for Removing Metal. Mr. Ferris' paper will be abstracted in a future issue of Mechanical Engineering and will be accompanied by the discussion. Mr. Parsons' paper appears in abridged form in this issue.

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[2] Otis Elev. Co., New York City. Mem. Am.Soc.M.E.
[3] Chief Engineer, The G. A. Gray Co., Cincinnati, Ohio. Mem. Am.Soc. M.E.
[4] Chief Mech. Engr., Reed-Prentice Co., Worcester, Mass.
[5] Treasurer and Works Manager, The Acme Machine Tool Co., Cincinnati, Ohio.
[6] Chief Mech. Engr., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
[7] Vice-President, The Oilgear Co., Milwaukee, Wis. Mem. Am.Soc.M.E.
[8] Chief Engr., Kempsmith Milling Machine Co., Milwaukee, Wis. Mem. Am.Soc.M.E.

Session on Education and Training

AT THE Session on Education and Training for the Industries held Tuesday, December 5, the program was presided over by W. W. Nichols, Chairman of the Committee on Education and Training for the Industries. The presentation of the subject was in the form of a report of the Committee which was introduced by Mr. Nichols. The report itself consisted of three parts, one on Extension and Correspondence Schools, by James A. Moyer;[1] a section on Industrial Education as Represented in Schools, by C. R. Richards;[2] and the final section on Schools for Apprentices and Shop Training, by R. L. Sackett.[3] Each of the sections of this report were presented separately and discussed. The report of the Committee with a complete account of the discussion will appear in the March issue of Mechanical Engineering.

Research Session

A GROUP of five notable papers resulting from the activities of the Research Committee were presented at the Session on Tuesday afternoon, December 5, with Walter Rautenstrauch, Chairman of the Research Committee, as presiding officer.

In his paper entitled A New Method of Determining the Effect of Speed upon the Strength of Gear Teeth, Wilfred Lewis[4] discussed the analytical work on this subject performed by Oscar Lasche, Professor Marx and C. H. Logue, and described a modification of his gear tester as a device for measuring exactly the relation of speed to pressure. This paper appeared in the December issue of Mechanical Engineering. The discussion, which was contributed by Messrs. E. D. Church, Carl G. Barth and G. H. Marks substantiated the need for further investigation of this subject.

The report of the Research Sub-Committee on Sudden Initial Pop Lift of Safety Valves removed the fear that a relatively large sudden steam discharge from the boiler or the sudden stopping of such a discharge may cause dangerous shock to the boiler.

The Committee which was made up of P. G. Darling, Chairman, E. F. Miller, W. E. Jerauld, G. H. Clark, I. E. Moultrop, A. M. Houser, A. L. Fitch, and G. S. Coffin, conducted two series of tests, one at Boston with the work carried on by three thesis men at the Massachusetts Institute of Technology, and one at Bridgeport.

In the tests an extremely sensitive pressure indicator of special design was used which employed a thin diaphragm with a maximum allowable movement of 0.007 in. This diaphragm was balanced between the pressure of the steam or water in the boiler and an outside air pressure. Any change in pressure would cause a movement of the diaphragm which could be detected by a microphone or an electric light. In the Bridgeport, tests which were conducted on a 94-hp. B. & W. water-tube boiler at 300 lb. pressure, the Committee selected four points at which shock on sudden relief of steam would be most likely to occur as follows:

a At the upper or front ends of the tubes where the water in circulating takes nearly a right-angled turn into the front header

b At the top of the front header where it enters the drum

c Against the headers of the drum

d At the middle of the drum.

The quick-opening test valve was arranged so that the discharge of steam could be varied from six to seventeen times the capacity of the valve assigned in the A.S.M.E. Boiler Code. The test showed, however, that even with steam discharging from the valve at the maximum rate of 95,000 lb. per hr. there was no indication of change in pressure from any of the four pressure indicators. The closing paragraph of the report is as follows:

> This investigation might be continued with prolonged trials on different types of boilers, under different conditions of steaming, and with additional points of attachment for the diaphragm indicators. However, considering the fact that no degree of pressure increase or shock whatever has been detected under the severe steam-discharge conditions tried, we believe that it is extremely unlikely that any boiler conditions would be found so radically different as to produce a shock. In other words, if a pressure-increase shock could be produced by any reasonable boiler operation, we believe that the conditions of our tests were representative enough to have detected at least some trace of such shock.

The only discussion on this report consisted of expressions of relief that no conditions of shock were set up upon the opening of safety valves.

The paper on Torsion of Crankshafts, by S. Timoshenko,[1] resulted from the work of the Committee on Stresses Due to the Vibration of Shafting. This paper will appear in abstract in a later issue of Mechanical Engineering. There was no discussion.

The two papers on flow of gases, one entitled The Effect of Pulsations on the Flow of Gases, by Horace Judd[2] and D. B. Pheley,[3] and the other on Orifice Coefficients, by J. M. Spitzglass,[4] were related to the work of the Sub-Committee of Research on Fluid Meters. Abstracts of these papers with the discussion will appear in later issues of Mechanical Engineering.

Steam Table Research

PROFESSOR A. G. Christie presided over an exceedingly interesting session on Tuesday afternoon, December 5, at which the problems and progress in research work were discussed. George A. Orrok, Chairman of the Executive Committee of the Steam Table Fund, told of his correspondence with physicists and engineers in France and England to secure interest in further research on this subject in those countries, and to develop all possible sources of information so that the tables when finally completed will be ready for adoption internationally. Dr. Harvey N. Davis told of the work being carried on at Harvard on the Joule-Thomson effect and introduced Dr. R. V. Kleinschmidt who is conducting this work. Dr. Davis also read a report from Dr. Frederick G. Keyes, of the Massachusetts Institute of Technology, who is preparing to handle one phase of the research. Dr. N. S. Osborne, of the Bureau of Standards, told of the preliminary study that is being made of the calorimetry of fluids as the basis of part of the program the Bureau of Standards will carry on.

The proceedings of this session are being more carefully prepared for publication at a later date.

First General Session

AT THE First General Session Tuesday, December 5, at which Arthur L. Rice, Vice-President of the Society, presided, three papers were presented. The first paper, by W. L. Wotherspoon,[5] on Refinery and Rolling Mill for Monel Metal at Huntington, W. Va., describes the steps taken in selecting the site for the location of the mill. The paper also deals with the layout of the plant, emphasizing some features of design of particular interest. There was no discussion on the paper. It will appear in abstract in a future issue of Mechanical Engineering.

The second paper, by E. W. Noyes[6] and H. V. Sturtevant,[6] entitled The Size of Dry-Vacuum Pump to Employ in a Given Case, proposed a rapid method for this determination. This paper will appear in abstract in a later issue of Mechanical Engineering with the discussion thereon.

A description of the Diesel Engine Used in German Submarine "U-117," prepared by William H. Nicholson,[7] was presented by L. H. Morrison. This will also appear in abstract in a later issue of Mechanical Engineering.

Session on Stokers

THE STOKER Manufacturers' Association coöperated with the Fuels Division of the A.S.M.E. in preparing the program of the Symposium on Stokers which was held Wednesday morning, December 6. Professor Breckenridge presided over the

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[3] Dean of Engineering, Pennsylvania State College, State College, Pa. Mem. Am.Soc.M.E.

[4] Pres. Tabor Mfg. Co., Philadelphia, Pa. Mem. Am.Soc.M.E.

[1] Cons. Engr. Vibration Specialty Co., Philadelphia, Pa.

[2] Prof. Hydraulic Engr. Ohio State University, Columbus, O. Mem. Am.Soc.M.E.

[3] Jr. Engr. U. S. Coast & Geodetic Survey.

[4] Vice-Pres. Republic Flow Meters Co., Chicago, Ill. Mem. Am.Soc.M.E.

[5] Construction Engr., International Nickel Co., New York, N. Y. Mem. Am.Soc.M.E.

[6] Sales engineers, Sullivan Machinery Co., Chicago, Ill.

[7] Designer, Engrg. Dept., Westinghouse Elec. & Mfg. Co., Camden, N. J.

presentation of the following papers: Development and Use of the Modern Chain Grate, T. A. Marsh; Overfeed Stokers of the Inclined Type, G. I. Bouton; Design and Operation of Underfeed Stokers, H. F. Lawrence; and Chronological History of Stoker Development to the Present Day, A. H. Blackburn. The first three of these papers are abstracted on pages 14 to 21 in this issue of Mechanical Engineering and are followed by the discussion.

Railroad Session

VOLUMINOUS discussion was brought out at the Session of the Railroad Division on Wednesday, December 6. James Partington, Chairman of the Railroad Division, presided over the presentation of three papers, one by G. H. Hartman[1] on Steam Distribution in the Locomotive, one by F. H. C. Coppus[2] on Mechanical Draft for Locomotives, and one by R. Eksergian[3] on Stresses in Locomotive Frames.

Mr. Hartman's paper appeared in abstract in the December issue of Mechanical Engineering. O. W. Young[4] submitted a lengthy written discussion in defense of the steam distribution accomplished by locomotive valve gears of all recognized designs. He came to the conclusion that there is a practical necessity in locomotive engines for moderately large cylinder clearance, variable points of release, variable points of closure and variable points of pre-admission. He presented an indicator diagram showing steam distribution by comparing the results of the Pilliod valve and the conventional valve, and questioned whether the factors determining cutoff, release, etc., will not necessitate the readjustment of valve events to approximately the same points in the cycle that existing locomotive valve gears now place them. In closing he stated that practical refinements in locomotive steam engines must be limited to greater accuracy in registering valve events for prolonged service periods and increased port and passage areas proportioned to increases in cylinder sizes.

J. J. Jones[5] stated that in his opinion the defects of the locomotive valve gear are much exaggerated. He questioned whether any improvements in the device described by Mr. Hartman would be sufficient to warrant the additional cost of the device.

After a brief review of the steps in the progress of steam-locomotive development, L. D. Freeman[6] stated that by no line of reasoning can the quality of the steam entering the cylinder have any bearing upon the events produced by purely mechanical movement of the valve arrangement. Mr. Freeman suggested as proper steps in improving locomotive cylinder performance the separation of the action of the steam side of the valve from the exhaust side and the adjustment of the steam clearance space to properly absorb the inertia of the reciprocating parts.

H. B. Oatley[7] criticised the author's derogatory treatment of arches, feedwater heating and superheating and presented a table giving the per cent of water and fuel saving for superheated steam at several temperatures for various cutoffs and pressures as compared with dry saturated steam. Mr. Oatley called attention to the fact that in spite of the large amount of heat required to produce a pound of superheated steam over that required to produce a pound of saturated steam, the net savings are more than could be expected from any change of steam distribution.

H. H. Vaughan[8] questioned the treatment by Mr. Hartman of the subject of cylinder condensation and the effect of clearance. Mr. Vaughan called attention to the large amount of experimental and theoretical work which has been done on the locomotive in the past twenty years which does not seem to be reflected in the statements in Mr. Hartman's paper.

R. C. H. Heck[9] compared the Pilliod valve to the old Meyer gear.

The paper by R. Eksergian on Stresses in Locomotive Frames is a preliminary analysis of the major reactions brought on the locomotive frame as well as of the nature of frame action as regards variation of bending moment, shear, etc., for definitely supported types of frames. The first section of the paper is a careful analysis of the various methods of equalization, spring design, and the nature of cab supports in electric locomotives. This is followed by a section dealing with the dynamics of the steam locomotive where the variation of torque and a quantitative investigation of the various oscillations are discussed in detail. Further, a careful analysis of the variation of side-rod loads and journal-bearing loads is included. The succeeding section deals with electric-locomotive drives and the major reactions brought on the frame. This section includes the dynamics of the electric side-rod drive, which discussion augments the previous one on side-rod loads in steam locomotives. The next section discusses the dynamics of braking, its change in load on the equalization and the reactions brought on the frame. In this section is included a brief discussion of bumping loads and dynamical loads on the drawbar. Finally the nature of the lateral reactions and the dynamics of lateral oscillations on entering a curve, etc., are discussed, a short recapitulation of the static reactions while on a curve being also given.

Due to delay in the preparation of advance copies of this paper it was not possible to secure proper discussion on such a highly complicated subject. It is planned to have the paper submitted for discussion at a later meeting.

W. E. Woodard,[1] Chairman of the Research Committee of the Railroad Division, emphasized the importance of the paper as the basis for experimental research on frame stresses. Other comments were made by A. H. Houston, George M. Eaton, Selby Haar, Clement F. Street, and W. E. Simons.

The paper by F. H. C. Coppus on Mechanical Drafting of Locomotives was also well discussed. This paper will appear in a later issue of Mechanical Engineering with an abstract of the discussion.

Second General Session

THE SECOND General Session of the meeting was held on Wednesday morning, December 6, under the chairmanship of Walter S. Finlay, Jr. Three papers were presented. Stresses in Cylindrically Shaped Rotors of Uniform Diameter, by C. M. Laffoon,[2] developed a general theory and analyzed mathematically the stresses in cylindrical rotors of uniform diameter such as are commonly associated with different classes of machinery. This paper with its discussion will appear in complete form in Transactions.

The second paper, on the Design of Flywheels for Motor-Driven Impulse Machines, prepared by C. O. Rhys,[3] was presented by S. C. Stovall, of Atlanta. In his paper Mr. Rhys analyzed the torque and speed curves for such machines and derived expression by which the characteristics of these curves may be determined. This paper with its discussion will also appear in Transactions.

The paper, on Stress Distribution in Electric-Railway Motor Pinions, by Dr. Paul Heymans[4] and A. L. Kimball, Jr.,[5] described the photo-elastic method by which this stress is determined. The paper also reported and discussed the causes of rupture of gear pinions in electric railway motors. An abstract of this paper with discussion will appear in the February issue of Mechanical Engineering.

Power Session

FIVE papers were presented at the Power Session on Thursday morning, over which John H. Lawrence, Chairman of the Power Division, presided. The paper on The Commercial Economy of High Pressure and High Superheat in the Central Station, by Geo. A. Orrok, appeared in Mechanical Engineering for December. A running account of the discussion of this paper is given below. The paper by Linn Helander on Feed Heating for High Thermal Efficiency will appear in the February issue of Mechanical Engi-

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[3] Engr. Baldwin Loco. Works, Philadelphia, Pa. Mem. Am.Soc.M.E.
[4] Engr., Pyle-National Co., Chicago, Ill.
[5] Valve Gear Designer, American Loco. Co., Schenectady, N. Y.
[6] Asst. Supt. M. P., Seaboard Air Line R. R., Portsmouth, Va.
[7] Chief Engr. Superheater Co., New York City. Mem. Am.Soc.M E.
[8] Const. Engr., Montreal, Quebec, Canada. Mem. Am.Soc.M.E.
[9] Prof. M. E. Rutgers College, New Brunswick, N. J. Mem. Am.Soc.M.E.

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[2] Power Engrg. Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.
[3] Georgia School of Technology, Atlanta, Ga. Mem. Am.Soc.M.E.
[4] Mass. Inst. of Tech., Cambridge, Mass. Assoc-Mem. Am.Soc.M.E.
[5] Genl. Elec. Co., Schenectady, N. Y.

neering, but a brief abstract of the paper and discussion is included in the present account of the meeting. An extended abstract of Paul W. Thompson's paper giving the results of tests on different types of baffling in a Type W Stirling boiler appears in this issue and is followed by an abstract of the discussion it elicited. The papers by Sabin Crocker and S. S. Sanford on The Elasticity of Pipe Bends and by B. N. Broido on High-Temperature and High-Pressure Steam Lines, together with the discussions thereon, will appear in abstract in future issues. Mr. Broido's paper was presented by title and will be discussed at the January 4 meeting of the Metropolitan Section, A.S.M.E.

Discussion of Paper by Geo. A. Orrok on The Commercial Economy of High Pressure and High Superheat in the Central Station

The discussion of Mr. Orrok's paper and its appendices on the properties of metals at high temperature and the cost of piping materials by W. S. Morrison, was opened by John A. Stevens[1] who presented by means of lantern slides data on the influence of coal cost and load factor on the efficiency and first cost of a power plant. Comparing a refined design, 15,000 B.t.u. per kw-hr., with an original design, 20,000 B.t.u. per kw-hr. and costing $100 per kw., his figures showed that with a 40 per cent load factor the increase in permissible cost in the refined design varied from 6.9 per cent with coal at $2 per ton to 69 per cent with coal at $20 per ton, while these percentages would be 10.3 and 103.3 if the load factor were 60 per cent.

Henry B. Oatley[2] questioned the correctness of assuming a turbine efficiency of 78 per cent with pressures as high as 1200 lb., saying that the increase in density at this pressure would result in greater friction losses in the turbine. He also pointed out that the specific heat transfer from the inner wall of a superheater to the steam decreased with the density and velocity of the steam. It was therefore not possible, he wrote, to produce a total steam temperature of 1100 deg. without considerably increasing the temperature of the metal tube wall. The only known means of holding down the excess of metal temperature was the employment of much higher steam velocities and pressure drops, the use of small tubes, and the restratifying of the steam during the superheating processes so as to mix the denser core with the more rarefied stratum in contact with the tube wall.

C. H. Smoot,[3] in a written communication, compared the relative advantages of increased pressure versus increased temperature and showed that at present the greater advantages lay with the former. He also pointed out that the regenerative cycle should be given more careful study. In his opinion the present type of turbine was not suited to this cycle, and his reasons formed a part of his discussion. He thought that an extension of our knowledge of the properties of steam at high pressures might indicate an even greater improvement in thermal economy by the use of high-pressure saturated steam than was now deduced from our inaccurate data.

Walter J. Wohlenberg[4] presented a written discussion which included a revised table of results (author's Table 1), the comparisons in which were based on the single-stage regenerative or heat-balance cycle of the modern power plant instead of the Rankine cycle used by the author.

I. E. Moultrop[5] said that while he was not as optimistic as the author that the manufacturer would be able to build apparatus for such high pressures as those considered in the paper, he did feel that the boiler and turbine could be built without great difficulty. The piping and valves between these two units, he said, would give considerable trouble. He concurred heartily with the author's fourth conclusion that there was more economy to be gained by close study of operation and construction losses than in an attempt to increase widely the temperature range of heat cycles.

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[3] Engineer, Rateau, Battu, Smoot Co., 140 Cedar St., New York, N. Y. Mem. Am.Soc.M.E.

[4] Asst. Prof. M.E., Sheffield Scientific School, Yale University, New Haven, Conn. Mem. Am.Soc.M.E.

[5] Asst. Supt. Constr. Bureau, Edison Elec. Illum. Co., 39 Boylston St., Boston, Mass. Mem. Am.Soc.M.E.

Peter Junkersfeld[1] said that the final question with any central station was always, Does it pay? In discussing the curves of the author's Fig. 2, especially that called "Extra fixed charges per kw-hr.," he showed that the determining factor of this item was the generator capacity factor. This factor, which was the ratio of the actual output to the possible output of a steam turbine as rated and all its accessories when averaged over a period of years, was much less than usually supposed, especially among central stations which had a substantial annual average increase in output.

An examination of the experience of 7 companies with 14 power stations and 92 steam turbines, aggregating 1,730,000 kw. rating, showed that in substantially the same 12 months' period one had had an average generator capacity factor on all its turbine units of 44 per cent and another of 25 per cent. The extra fixed charges per kw-hr. for the latter would be almost double that for the former.

An average experience curve for these 7 companies, all in large and growing cities, indicated a capacity factor of about 58 per cent on turbines one year old and 30 per cent or less on turbines ten years old.

The falling off with age of the capacity factor of turbines reflected good operating procedure with improved equipment in the successive installations. The fact that only one company operated its one-year-old turbines at 77 per cent, another at 52 per cent, and the third at only 23 per cent, and that the average of 10 turbines 2 years old operated by 6 companies was only 50 per cent, indicated that there was still very great room for improvement in construction and operation of equipment with what might today be called moderate pressures and superheat.

In all of the foregoing, wherever reference was made to turbine experience it meant not only the turbine proper, but also on one end the condensing equipment, piping and other mechanical accessories, and on the other end the generator, the excitation, the switching equipment and other electric accessories.

The development toward higher steam pressures and superheat had been under way many years and would inevitably continue. It should be given every reasonable encouragement consistent with established scientific facts and sound economic possibilities. It should be remembered however that this development in the past in a broad and overall aspect had tended toward lower construction as well as lower operating costs of the station. The development now immediately before us seemed to tend toward higher costs of construction and of operation with the exception of fuel. It thus would become even more necessary than heretofore to determine proper balances between fuel saving and what Mr. Orrok had called "extra fixed charges per kilowatt-hour." The latter was, therefore, particularly important and especially because experience had shown that it varied so widely from turbine to turbine from station to station, from company to compnay or city to city and from year to year.

A. M. Houser[2] presented a written discussion in which he pointed out that the values given by the investigations by Crane Co. on cast steel should be considered conservative.

Henry D. Hibbard[3] sketched briefly the behavior of boiler steel when subjected to increase of temperature. The paper, he said, gave a partial résumé of the properties, at elevated temperatures and for a limited time, of metals which would be employed in superheated-steam containers contemplated by the paper, but no one, so far as he knew, had investigated how the properties of such metals would be affected by long use in boilers for making highly superheated steam and in apparatus for handling it.

V. T. Malcolm[4] contributed an illustrated discussion, too extensive for abstract here, on metals for valves.

D. S. Jacobus[5] said that, speaking from the boiler maker's standpoint, pressures up to 1200 and even 1500 lb. might be attained, whereas there were special features of design that had to be carefully considered when it came to the construction of a unit

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[2] Engineer of Product, Crane Co., 4100 S. Kedzie Ave., Chicago, Ill. Mem. Am.Soc.M.E.

[3] Consulting Engineer, 144 E. 7th St., New York. Life Mem. Am.Soc. M.E.

[4] Metallurgical Engineer, Chapman Valve Co., Indian Orchard, Mass.

[5] Advisory Engineer, The Babcock & Wilcox Co., 85 Liberty St., New York. Mem. Am.Soc.M.E.

of large size for power-plant work and no large-sized units for these pressures had so far been constructed. He agreed with Mr. Orrok that temperatures up to 750 deg. should not be exceeded. He spoke of the difficulties of designing fittings, particularly flanges for such pressures and expressed the opinion that it would seem best in the design of flanges to make the bolts the weaker element as in case of overstrain they could be readily replaced, whereas should the bolts be made strong enough to dish and distort the flanges, the flanges would have to be replaced. He also stated the need of data to show whether the elastic limit of steel at high temperatures would be permanently elevated in the case of an overstrain in the same way as at ordinary temperatures. Experiments on this feature would be most useful. He reviewed the experiments on high-pressure boilers made by Perkins and published in a book by Galloway in London in 1830.

H. L. Whitney[1] said that there had been built and kept in operation for over two years a pipe line on 1500 lb. and 850 deg. fahr. The largest point was 36 in. in diameter. There was no trouble with steam piping from increased pressure he, said, if the temperature was kept below 700 deg. fahr.

Robert Cramer[2] pointed out the relative theoretical advantage of raising pressure rather than temperature.

Max Toltz[3] said that there was a middle course between high and low pressures and temperatures of steam which was to be found in the use of resuperheated steam between stages. He had seen an experimental plant in Europe in which the economies were very high.

Francis Hodgkinson[4] said that manufacturers were embarrassed by lack of standards for pipes for the higher pressures and urged the Society to undertake the formation of such standards. He thought that the tendency to use alloy steel for bolts was unfortunate because of the danger of mixing such bolts with those of commercial steel when dismantling machinery.

Nevin E. Funk[5] spoke of some of the difficulties of operating a high-pressure power station.

Oscar F. Junggren[6] said that the discussion of high pressure was not new. As had been said, if high pressure did not pay it was useless. There had been in the past a gradual increase in pressures, each accompanied by a development of apparatus, and every increase had paid so far. Why, therefore, doubt that there could be further gain? Until some one gave higher pressures a trial, he said, no one could know what the efficiencies might be.

T. E. Keating[7] wrote that granting that the gains in individual apparatus, desirable as they might be, must be relatively small, then improved thermal efficiency of steam stations must depend upon:

1 The use of regenerative cycles which would divert from the turbine the latent heat of part of the steam, thus reducing the losses to the condenser

2 The use of heat-reclaiming apparatus for eliminating losses in the flue gases

3 The utilization of a greater range of the heat cycle.

Referring to the paper by Messrs. Orrok and Morrison, and particularly to the appendix including test data on metals under high temperatures, it was evident, he wrote, that an increase of the temperature range was today more of a problem for the chemical and physical laboratories than for central stations, as modern stations had nearly reached the limits for materials now commercially applicable.

The use of the high pressure range of 1200 to 1500 lb. suggested by the paper, he wrote, would require some new principles of turbine design, as with present designs it was probable that a greater efficiency would be obtained with 500 lb. pressure and 280 deg. superheat than with 1500 lb. and 150 deg. superheat, both conditions being equivalent to a total steam temperature of approximately 750 deg. The selection of a proper pressure and temperature depended upon combined commercial and engineering judgment applied to the problems surrounding the particular station involved, but a discussion of this factor would be of value.

[1] Director and Sales Manager, M. W. Kellogg Co., New York.

[2] Cramer Mfg. Co., 387 10th St., Milwaukee, Wis., Mem. Am.Soc.M.E.

[3] M. E., Toltz, King and Day, Inc., 1410 Pioneer Bldg., St. Paul, Minn. Mem. Am.Soc.M.E.

[4] Chief Engineer, Westinghouse Elec. & Mfg. Co., S. Philadelphia Wks., Lester, Pa. Mem. Am.Soc.M.E.

[5] Operating Engineer, Philadelphia Elec. Co., 1000 Chestnut St., Philadelphia, Pa. Mem. Am.Soc.M.E.

[6] Engineer, Turbine Dept., Genl. Elec. Co., Schenectady, N. Y. Mem. Am.Soc.M.E.

[7] General Engineer, Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa. Mem. Am.Soc.M.E.

Discussion of Paper by Linn Helander on Feed Heating for High Thermal Efficiency

In order to make the discussion intelligible to those who did not attend the meeting and who have not obtained a copy of the pamphlet, we present the following brief summary of Mr. Helander's paper.

The author investigates the problem of determining the correct feedwater temperatures for conditions of high thermal efficiency. For illustrative purposes he bases his calculation upon several assumed stations of 25,000 kw. capacity using various methods of feedwater heating. The steam conditions assumed for all plants are steam pressure, 330 lb. gage; superheat, 200 deg. fahr.; vacuum on main unit, 29 in. To illustrate the influence of factors such as the water rate on the main unit and the slope of the Willans line of this unit, the Rankine-cycle efficiency of the bled steam and the Rankine-cycle efficiencies of the house turbine, two cases—designated Case 1 and Case 2 respectively—are worked out for each arrangement of feedwater heating. In the various solutions arrived at by the author the feedwater derives its heat from three possible sources: (*a*) the feedwater of the main unit is used as the condensing water of the house turbine, thereby absorbing all the heat in the steam exhausting from the house turbine; (*b*) steam is bled from the main unit in such quantities and at such temperatures as to increase the amount of heat delivered to the feedwater by the house turbine, and (*c*) before entering the boiler the feedwater may pass through the economizer.

Under Case 1 the Rankine-cycle efficiency for the bled steam based on the steam pressure on the turbine side of the throttle was approximately 67 per cent, the slope of the Willans line was 12 lb. per kw-hr. and the water rate of the main unit when carrying the gross station load was 10.6 lb. per kw-hr. The combinations of feedwater heating investigated under Case 1 included single- and double-stage heating and were as follows. For single-stage heating (*a*) no economizers, no bleeding, 1600-kw. house turbine, (*b*) no economizers, bleeding, 650-kw. house turbine; (*c*) 50 per cent economizer surface, bleeding, 650-kw. house turbine; (*d*) 100 per cent economizer surface, bleeding, 650-kw. house turbine. The greatest thermal efficiency is obtained with the last of these combinations and at a feed temperature of approximately 180 deg. fahr.

For double-stage heating and for approximately the same combinations of apparatus supplying the heat, with the exception of the substitution of a 1400-kw. house turbine for the 1600-kw. turbine and of economizers of slightly different area, the same general conclusions are drawn: that is, that the best combination is obtained with the maximum economizer surface, the maximum amount of bled steam, and the smaller house-turbine unit. For the cases investigated the feedwater temperature for best economy lies between 180 and 220 deg. fahr.

Single-stage, double-stage, and four-stage heating are worked out for Case 2 in which the Rankine-cycle efficiency of the bled steam is 80 per cent, the slope of the Willans line 9 lb. per kw-hr. and the water rate in the main unit 10.26 lb. per kw-hr. In general the same combinations of feed-heating apparatus were used with Case 2 and the results for single-stage, double-stage, and four-stage heating show that maximum economy is obtained with a maximum economizer surface, a maximum amount of bleeding, and the use of the smallest house-turbine unit. The feedwater temperatures for Case 2 are for single-stage heating, 160 deg., for double-stage heating, between 160 and 200, and for four-stage heating, between 190 and 220 deg.

The author devotes two paragraphs to discussing the effect of air preheaters, but does not bring these effects into his numerical calculations.

In conclusion he says that so many factors enter into the determination of the proper feedwater temperature that figures determined for one station should not be applied to another. The temperature should be lower for plants using single-stage heating than for those using multiple-stage heating and also should be lower for plants using economizers than for plants not using economizers.

Efficiencies of auxiliary apparatus as well as of the main generating units have their influence. If the feedwater temperature be raised much above 212 deg. fahr., factors incident to the use of pressures well above atmosphere in the auxiliary exhaust piping come into play. The proper feedwater temperature is dependent somewhat upon the initial steam pressure and temperature and on the temperature of the condensate, increasing as these increase. It is quite impossible, therefore, to determine, except within wide limits, feedwater temperatures applicable to all plants, and the purpose of the paper has been rather to indicate in a broad way the effect of feedwater temperatures on power-plant efficiency, leaving out the matter of costs, and to give some basis for estimating the sacrifice in fuel made to assure practicable operation of the feedwater-heating system as laid out for a particular station.

The discussion of the paper was opened by George G. Bell[1] who said that about a year ago he had made a study of the heat balance of the Windsor Station of the West Penn Power Co. and at that time had determined 210 deg. to be the most economical feed temperature. The turbine was a 30,000-kw. G. E. unit, the boilers 1450 hp. and the economizers had 8341 sq. ft. of surface. Two-stage and three-stage heating were studied after Mr. Helander had begun the preparation of his paper and the results, with economizers, of one-, two- and three-stage heating produced curves practically parallel with the author's: about 1.75 per cent above. These results showed a saving of about one per cent, comparing two- with one-stage heating, and about one-half of one per cent, comparing three- with two-stage heating. The temperatures he obtained did not check as closely as those obtained by the author. They were, with economizers, 200 deg. fahr. for one-stage, 235 for two-stage, and 270 for three-stage heating. Without economizers they were 265 deg. fahr. for one-stage, 290 for two-stage, and 310 for three-stage heating. The savings without economizers were about $1^1/_2$ per cent between one- and two-stage, 0.8 per cent between two- and three-stage, and 0.5 per cent between three- and four-stage heating. These two studies, he said, would indicate that even with economizers the feed temperature should be at least 210 deg. fahr.

T. E. Keating[2] read a discussion in which he said that it was somewhat surprising to find that in the application of economizers with 350 lb. boiler pressure and stage heating the most efficient temperature was close to 200 deg. fahr., as it had been rather generally believed that the efficient use of economizers demanded a somewhat lower temperature. The use of multi-stage heating was receiving considerable attention, he said, in central-station engineering, and its application involved many practical problems. He also discussed the question of the exhaust pressure at which the house turbine should be operated, and the preheating of air.

W. M. Keenan[3] spoke of some studies of bleeding at one point which had been made in connection with a new Brooklyn station. The results were surprising in that they showed that the best point to bleed the turbine was not in the vacuum range, as had been supposed, but at about 25 lb. absolute pressure. Continuing the studies to include bleeding at two points showed that best conditions prevailed with bleeding at 12 lb. and 100 lb. absolute pressure.

Prof. A. G. Christie[4] said that he was becoming convinced heating should be done by the steam from the main unit and the power should be generated by it, thus doing away with the house turbine.

Oscar F. Junggren[5] reiterated Professor Christie's statement and pointed out a further advantage in bleeding the main unit in that the more congested low-pressure end of the turbine was relieved thereby.

Francis Hodgkinson[6] said that he was surprised that the author had laid so much stress on the relations of the house turbine, because the house turbine was not going to be used very much in the future on account of the greater efficiency of the main unit and the greater efficiency of bleeding from it for feedwater heating.

Nevin E. Funk[1] said that while stage heating might prove to be more efficient theoretically, it would involve greater complications in the power plant. Simplicity made for more efficient operation, and a scheme which had great theoretical advantages on paper might not prove so in actual operation because the human element would have to be considered.

F. H. Rosencrants[2] presented a written discussion in which he showed, using the author's assumed condition, that the theoretical Rankine efficiency would be 35.35 per cent, while that of the Carnot cycle would be 40 per cent. Assuming it possible to approximate the Carnot cycle as readily as the Rankine, he showed that the saving by attempting the former ideal would be 13.15 per cent compared to the latter. He spoke further of the tendency of many engineers to ignore the superiority of the Carnot cycle over the Rankine. Accepting the figures given in the papers, he said, led one to question whether an economizer had a place in a central station of modern design with multi-stage bleeding, in view of the fact that a multi-stage bleeder heater system and additional boiler surface was likely to be less expensive than the economizer installation.

C. M. Hardin[3] wrote that every one concerned with steam-power generation realized that reliability was of first importance and must be obtained even at the sacrifice of plant efficiency and other requisite factors. Without discounting reliability, it was, however, vitally important that high efficiency be obtained. To obtain maximum plant efficiency every integral part of the station equipment must be of such correlative design and construction as would individually produce and maintain high efficiency. Stage bleeding from the main prime mover was, without question, the method that did give highest feedwater heating efficiency as compared to using the house turbine or other steam-driven auxiliaries. If stage bleeding should even in the slightest degree tend toward unreliability as regards continuity of service, the problem was to perfect the equipment used and allied with the scheme.

Session on Standardization

THE Session on Standardization, consisting of a program prepared by the Standing Committee of the A.S.M.E. on Standardization with the coöperation of the American Engineering Standards Committee, was held Thursday, December 7, with E. C. Peck, Chairman of the Standardization Committee, acting as presiding officer.

The first paper, by William J. Eynon,[4] was a progress report on the Program for the Standardization of Paper and Printing Machinery in which the new A.S.M.E. Committee on Printing Machinery is keenly interested. Mr. Eynon's paper, which was presented by Winfield S. Huson,[5] indicated the possibilities of standardization of printing presses, of which there were over two hundred sizes and styles in use today, and of folding machines with six hundred sizes and types. The first step in this simplification was a reduction in the number of sizes and grades of paper and Mr. Eynon told of the coöperative work being carried on by printers, printing-machinery manufacturers, lithographers, purchasing agents, and advertisers to secure the adoption of standard sizes of paper.

R. E. Rindfusz[6] expanded one phase of Mr. Eynon's paper by stressing the importance of reducing the number of items of paper as an important step in reducing idleness in paper-making machinery. He also pointed out that the important field for standardization was that of grade and trade names. This lack of fixed grade meant a multiplicity of brands with little or no difference. The addition of each brand of paper with its ramifications of color, sizes, weights and finishes meant an increase of 108 items with consequent increased complications in paper manufacture. Mr. Rindfusz commended the work of the Committee which was

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[3] Ross Heater & Mfg. Co., Inc., 2 Rector St., N. Y.

[4] Chairman of Standardization of United Typothetae of America, Washington, D. C.

[5] Consulting Engineer, New York City. Mem. Am.Soc.M.E.

[6] Secy., American Writing Paper Co., Holyoke, Mass.

carrying out the standardization program in a fair-minded, broad-gaged constructive manner.

W. C. Glass[1] also emphasized the importance of standardization of grades of paper as a step toward simplicity in selection of paper, fairness in competition, and simplification in the manufacturing processes.

F. A. Curtis[2] told of the coöperative work being carried on by the Bureau of Standards to secure simplification and standardization.

F. B. Gilbreth[3] bespoke support for standardization in any field as a step in developing industry. Mr. Kalkoff told of the progress which had already been made in the standardization of type and stated that the over-equipment in the printing industry in New York State was about 75 per cent and throughout the country about 150 per cent, because printers purchased special machinery to do special jobs, and when the jobs were finished the machinery was idle and might never be employed. W. Green emphasized the importance of standardization from the printers' point of view.

In his closing remarks Mr. Huson pointed out the importance of the printing industry and directed the attention of the engineering profession to its problems. He stated that the further development of this industry would challenge the skill and precision of the trained mind and indicated that the function of the Committee on Printing Machinery was to bring the engineering point of view to the assistance of the industry.

The paper on Size Standardization by Preferred Numbers, by Messrs. C. F. Hirshfeld[4] and C. H. Berry,[5] which appeared in the December issue of Mechanical Engineering, brought out a very heavy discussion. The points developed therein require very careful editorial consideration and a more complete résumé of it will appear in a later issue of Mechanical Engineering. Written discussions were submitted by C. G. Barth, Buckner Speed, F. O. Hoagland, L. D. Burlingame, L. B. Tuckerman, E. R. Hedrick, A. E. Kennelly, B. M. Eaton, E. H. Rigg, W. A. Durgin, W. A. DelMar, Major G. F. Jenks, C. J. Oxford, R. Trautschold, and E. Buckingham. Those orally discussing the paper were F. B. Gilbreth, A. L. DeLeeuw, W. H. Timly, and Alfred B. Carhart.

Safety Engineering

THE American Society of Safety Engineers joined with the Safety Codes Committee of the A.S.M.E. in the preparation of the program for the Session on Thursday morning, December 7, devoted to Safety Engineering. John W. Upp, Chairman of the Safety Codes Committee, presided, and the following papers were presented: Safety Codes, M. G. Lloyd; Safety Engineering in Connection with the Compression of Gases, A. D. Risteen; Safety Codes for Grinding Wheels, G. E. Sanford; and Some Hazards of the Logging Industry, John A. Dickinson. These papers will appear in abstract in a later issue of Mechanical Engineering.

Ordnance Session

AT THE Session on Ordnance held Thursday afternoon, December 7, with Waldo H. Marshall, Chairman of the Ordnance Division, in the Chair, two papers recording wartime ordnance manufacturing experience were given. R. A. Vail[6] presented a paper on Methods Used in Manufacture of Gun Recoil Mechanism, and J. B. Rose[7] one on Machining and Lapping Very Deep Holes. An abstract of Major Rose's paper appeared in December Mechanical Engineering. An abstract of Mr. Vail's paper with the discussion on both papers will appear in a later issue.

On Tuesday, December 5, members of the A.S.M.E. witnessed a demonstration of the Christie amphibious gun mount and as a special feature of this session, motion pictures of the demonstration were shown. In addition, the War Department displayed pictures of motorized artillery and modern types of guns.

[1] Vice-Pres. United Printing Machinery Co., New York City. Mem. Am.Soc.M E.
[2] Head, Dept. of Paper, Bureau of Standards, Washington, D. C.
[3] Pres. Frank B. Gilbreth, Inc., Montclair, N. J. Mem. Am.Soc.M.E.
[4] Chairman, Research Dept. Detroit Edison Co., Detroit, Mich. Mem. Am.Soc.M.E.
[5] Engr. Detroit Edison Co., Detroit, Mich. Mem. Am.Soc.M.E.
[6] Assistant Production Engineer, Dodge Bros., Detroit, Mich. Mem. Am. Soc.M.E.
[7] Major, Ord. Div. U. S. A. War Dept. Fort Leavenworth, Kan. Mem. Am.Soc.M.E.

Aeronautic Session

PROF. E. P. Warner, Secretary of the Aeronautic Division, presided at the session on Aeronautics on Friday, December 7, at which the following papers were presented: Influence of Design on Cost of Operating Airplanes, Archibald Black;[1] The Airship for Long Haul Heavy Traffic Service, R. H. Upson;[2] and Air Navigation by R. W. Willson[3] and M. D. Hersey.[4] Mr. Black's paper appeared in the December issue of Mechanical Engineering. Abstracts of the other papers and discussion upon them will appear in a later issue.

Forest Products Session

ON Thursday afternoon, December 7, Robert B. Wolf, Vice-President of the Society, presided at the Session on Forest Products. The following papers, which will appear in abstract in a subsequent issue of Mechanical Engineering, were presented: New Factors Which Are Influencing Woodworking Machinery Design, S. Madsen;[5] Control of Lumber-Cutting Waste and Production, C. M. Bigelow;[6] Some Engineering Aspects of the Design of Musical Instruments, W. B. White;[7] Lumber Dry Kilns, Thomas D. Perry;[8] and Lumber Standardization, F. F. Murray.[9] Mr. Bigelow's paper is published in this issue and the other papers will appear in later issues.

Boiler Code Hearings

THE BOILER Code Committee held two hearings during the Annual Meeting. One on Monday morning, December 4, was devoted to the revision of the Code for Power Boilers. A number of groups entered into animated discussion of some of the features of the proposed Code. The safety-valve manufacturers discussed the limitation of the blowdown and multiplex casing; manufacturers of boilers for the oil country asked that the diameter of the dome be restricted to not less than 60 per cent; stamping was brought up by representatives of state and municipal inspectors; and there was also a discussion on the thickness of pipe walls. Although the Code for Unfired Pressure Vessels was not thrown open for discussion, there were a number present interested and they were given an opportunity to advance their views.

The hearing on Tuesday, December 5, on the Code for Low-Pressure Heating Boilers was taken up largely by protests against the requirement for preheating seams to be welded.

Hearing on Power Test Codes

AT THE Public Hearing on Monday, Dec. 4, the Test Code for Reciprocating Displacement Pumps and the one for Feedwater Heaters were discussed and a few changes suggested, after which it was recommended that the Council approve them for adoption as the recommended practice of the profession.

The First Power Exposition

THE first National Exposition of Power and Mechanical Engineering in New York City opened auspiciously on Thursday, December 7, and continued through December 13. Forty seven thousand five hundred and eighty visitors viewed the exhibits that filled one floor of the Grand Central Palace. The fact that this was the first show of its kind on a national scale makes it difficult to judge its value, but the comments of the visitors prove conclusively that a show of this character is needed and appreciated by those who are engaged in the design and operation of power plants. The Exposition was made up of over 100 exhibits and all classes of power plant apparatus and equipment, except large boilers and prime movers, were well represented.

[1] Consulting Engineer, Garden City, L. I. Mem. Am.Soc.M.E.
[2] Aircraft Development Corp., Detroit, Mich.
[3] Deceased.
[4] Physicist, U. S. Bureau of Mines, Pittsburgh, Pa. Mem. Am.Soc.M.E.
[5] M. E. Curtis Co., Clinton, Iowa. Mem. Am.Soc.M.E.
[6] Chief Engr. Cooley & Marvin Co., Boston, Mass. Mem. Am.Soc.M.E.
[7] Technical Editor, Music Trade Review, Chicago, Ill.
[8] Vice-Pres. and Secy. Grand Rapid Veneer Works, Grand Rapids, Mich. em. Am.Soc.M.E.
[9] Engr. Hardwood Mfgrs. Inst., Chicago, Ill. Jun. Mem. Am. Soc.M.E.

ENGINEERING RESEARCH

A Department Conducted by the Research Committee of the A.S.M.E.

More Information Service

THIS time it is an informational clearing house for the whole of science and engineering. The National Research Council in Washington is maintaining such a service as one of its major departments in order to promote research and to extend its usefulness to industry by increasing the availability of reliable information.

Mechanical engineers naturally will use the Engineering Library and the resources of their society to meet special and technical informational needs. But they are likely to find it distinctly worth while to use the Research Council Information Service as a source of help in the case of border-line subjects and such as lie entirely beyond the confines of mechanical engineering.

Research Information Service has a technical staff representing the chief divisions of science and technology. Members of this staff are constantly answering inquiries about research problems, methods, processes, apparatus, reports, and their relations to industrial progress. The Service specializes in sources. If it does not happen to have at hand the facts you need, it most likely can tell you where to find them.

Except as special search of the literature, compilation of a report, or copying of data make a charge necessary, the aid of Research Information Service is free. Mechanical engineers are cordially invited to use this new informational clearing house, not in place of the specialized service provided in the Engineering Research pages of MECHANICAL ENGINEERING, but in addition to it. The best possible way to find out about the usefulness of Research Information Service is to try it. The proper form of address is Information Service, National Research Council, Washington, D. C.

Research Résumé of the Month

A—Research Results

The purpose of this section of Engineering Research is to give the origin of research information which has been completed, to give a résumé of research results with formulas or curves where such may be readily given, and to report results of non-extensive researches which in the opinion of the investigators do not warrant a paper.

Air A3–22. A STUDY OF AIR-STEAM MIXTURES. This investigation was conducted by LeRoy A. Wilson, Research Associate in Mechanical Engineering, under the general direction of Dean C. R. Richards. It is the outgrowth of an investigation of the reheating of compressed air by Dean Richards, and J. N. Vedder, Research Assistant in Mechanical Engineering, the results of which have been published. In this earlier investigation the employment of steam as a reheating agent was found to result in an increased thermal efficiency for the mixture of air and steam, as compared with the use of either air or steam separately, in an engine operating expansively. The purpose in operating a reciprocating engine with a working medium composed of a mixture of air and steam was to determine the possible advantages in thermal efficiency resulting from the use of such mixtures having different proportions of the two components and with different initial temperatures of the compressed air.

The results of this experimental work have just been published as Bulletin No. 131 of University of Illinois, Engineering Experiment Station, Urbana, Ill. This bulletin treats the subject of air-steam mixtures in considerable detail, by both means of a theoretical discussion, and by reporting actual tests made with different proportions of air and steam at different initial air temperatures and under various load conditions. The thermal properties of various mixtures are presented in the form of Mollier charts which will greatly simplify the solution of problems connected with the subject. The bulletin contains 96 pages and its price is 75 cents per copy.

Steam Power A5–22. A STUDY OF AIR-STEAM MIXTURES. See *Air A3–22.*

Iron and Steel A6–22. THE PREPARATION AND PROPERTIES OF PURE IRON ALLOYS. Scientific Paper No. 453 of the Bureau of Standards, entitled The Preparation and Properties of Pure Iron Alloys, deals with fundamental principles involved in the manufacture of steel products. To protect life and property it is necessary that the architect and engineer know the kind of steel which should be specified for each use. To know what composition a steel should have in order to withstand a certain amount of strain or to meet necessary requirements, the effects on the steel of each of its constituents must be known. The general effects of each of these constituents have long been familiar, but technical difficulties have hindered really thorough studies of the specific and exact effects of each of the elements. Very pure iron is difficult to prepare, and it is even more difficult to add a controlled amount of some one constituent of steel to pure iron without some contamination.

In this investigation iron of practically 100 per cent purity was prepared by an electrical method similar to the method of silver plating in which the metal is deposited from a solution by the passage of an electric current. The iron is plated out, leaving the impurities behind. This iron was then melted in a vacuum to exclude the effects of gases which would be taken up from the air if melted in contact with it. The heating was done electrically, and the containing crucibles were made of chemically pure magnesium oxide.

This paper will be ready in a short time and may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 10 cents per copy.

Photography A2–22. PHOTOMICROGRAPHY OF PAPER FIBERS. This paper describes some of the more important factors in the photomicrography of vegetable fibers, especially those used in the paper industry. As regards illumination it is shown that the carbon arc can be advantageously replaced by an incandescent stereopticon lamp. Different types of objectives are discussed, and it is shown that the working qualities of most objectives may be greatly improved by the use of proper light filters, three types of which are discussed. It is shown that where an object lying in different planes is to be photographed, an objective of comparatively long focal length will give better results than one of shorter focal length, and that this arrangement requires a longer bellows extension. Different types of photographic plates are described and suggestions as to the best type of plate to use for photomicrographic work are given. Suggestions for staining and preparing the material to be photographed are included, as well as some regarding the value of photographs for permanent records and in the study and control of materials and mill processes. A short bibliography on photomicrography and related subjects is given.

This very timely paper, known as Bureau of Standards Technologic Paper No. 217, was prepared by R. E. Lofton, Associate Physicist at the Bureau of Standards. Address Superintendent of Documents, Government Printing Office, Washington, D. C. Price 5 cents.

Wood Products A5–22. PHOTOMICROGRAPHY OF PAPER FIBERS. See *Photography A2–22.*

B—Research in Progress

The purpose of this section of Engineering Research is to bring together those who are working on the same problem for coöperation or conference, to prevent unnecessary duplication of work, and to inform the profession of the investigators who are engaged upon research problems. The addresses of these investigators are given for the purpose of correspondence.

Corrosion B9–22. SOIL CORROSION OF IRON AND STEEL PIPE. The damage to buried pipe structures due to the corrosive action of soil is known to run into enormous sums annually. In order to throw further light on the ways and means of reducing losses from this source, the Bureau of Standards instituted, about a year ago, a very comprehensive investigation into the entire subject. This investigation has been undertaken first, to determine what types of soils throughout the country are especially corrosive to iron and steel; second, which kinds of iron and steel pipe are most resistant to the corrosive action of particular types of soils, and, third, the most practical means of reducing damage from this cause.

The work is carried on with active coöperation of the principal manufacturers of iron and steel pipe, the large public-utility corporations throughout the country as the principal users of pipe, and the Bureau of Soils of the Department of Agriculture. The steel and public-utility interests are incurring the major part of the expense of the investigation. The Bureau of Standards plans and directs the work. Approximately 9000 specimens of pipe have been furnished free of charge by pipe manufacturers.

Owing to the very urgent demand from many sources, it is planned to increase considerably the scope of this investigation. The brass manufacturers have requested that numerous brass specimens be included in the test, particularly of fixtures designed to be used with wrought-iron and cast-iron pipes. It is planned also to include a considerable number of specimens of pipe coated with various types of protective coatings. These will include some additional specimens of pitch-treated pipe, but will more particularly refer to metal-covered pipe, such as those covered by the various processes of galvanizing, also lead-covered pipe for which rather strong claims have recently been made. Arrangements have been made with the manufacturers of galvanized pipe and lead-covered pipe to furnish the necessary samples. These will be buried at the various locations when the first inspection of the iron pipes is made. Address Director of the Bureau of Standards, Washington, D. C.

Iron and Steel B9-22. Soil Corrosion of Iron and Steel Pipe. See *Corrosion B9-22.*

Radiation B1-22. Emissivity of Cotton Cloth. Attention has been previously been called to an investigation which the Bureau of Standards is conducting to discover a roofing material which will keep the inside of a balloon hangar at a minimum temperature when exposed to the sun. It was shown that the most efficient means for reducing the heating of the interior of the building by solar radiations is by covering the outside of the roof with a highly reflecting substance, such as white paint or asbestos, and painting the inside of the roof with aluminum paint which is a poor radiator of the low-temperature long-wave-length radiation emitted by the roof.

During the past month a similar study has been made of white cotton cloth such as it used for tents. As is well known, when a tent is exposed to the sun the interior becomes uncomfortably warm from the sunlight which is diffusely transmitted through the cloth, and in particular as a result of the heat rays emitted by the cloth. By covering No. 10 duck on the inside with aluminum paint it was found that the heat radiation into the interior of the tent reduced 86 per cent. If the aluminum coating is on the outside the arrangement is less efficient, the radiation into the interior being reduced by only 78 per cent. While No. 4 duck would be too heavy for tents, it is interesting to note that by applying a coating of aluminum paint to the interior the heat radiation is reduced from 78 to 81 per cent. It is obvious that while such a tent would be more comfortable in the daytime, during the night the use of the coating of paint would act in the opposite way and retain the heat generated within, thus maintaining a higher temperature.

Welding B2-22. Test of Welded Rail Joints. An investigation is being conducted at the Bureau of Standards on the strength of rail joints in coöperation with the committee on welded rails, and six preliminary tests have been made of typical rail joints used on street railways. For this purpose the large horizontal Emery testing machine has been employed. Two specimens of thermit-welded joints, 1 riveted fishplate joint, and 1 standard 7-in. railroad rail section, as well as 2 specimens of electric butt-welded joints submitted by the Lorain Steel Company have been tested. The preliminary tests showed wide variations in the strength of the joints made by the different methods, but sufficient information was obtained concerning the method of test to determine the best means for gripping the specimens as well as the most satisfactory design therefore.

D—Research Equipment

The purpose of this section of Engineering Research is to give in concise form notes regarding the equipment of laboratories for mutual information and for the purpose of informing the profession of the equipment in various laboratories.

Instruments and Apparatus D1-22. Sprague Dynamometers. The Division of Engineering, Brown University, has recently installed in oneof its laboratories two Sprague dynamometers each having a capacity oe 200 hp. These dynamometers may be used either separately or tofgether and are completely equipped with all the necessary auxiliary apparatus. With this apparatus power tests from 15 to 600 hp. may be made and the authorities of Brown University desire to make it known that these facilities are available. Those interested may address Prof. William H. Kenerson, Division of Engineering, Brown University, Providence, R. I.

CORRESPONDENCE

CONTRIBUTIONS to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities and policies of the Society in Research and Standardization.

The Accuracy of Boiler Tests

To the Editor:

I have read with very great interest the correspondence under this heading, and I am afraid that fear of taking up too much space in your columns prevents me from joining in the discussion on all the very many different points that have been raised. I will content myself, therefore, with the question of the amount of steam or power used auxiliary to the production of steam.

A very serious defect in the revised A.S.M.E. Boiler Test Code, which applies still more forcibly to the British Institution of Civil Engineers' Code, is the scanty attention given to this question of steam or power used auxiliary to the production of steam. The simplest boiler plant, merely for the sake of illustration, can be taken as one boiler only, without any accessories, evaporating say, 5000 lb. of water per hour, and working with an injector, in which case the real steam output of the plant—apart from the infinitesimal amount of energy used by the injector—is 5000 lb. of steam per hour, and the real net working efficiency of the plant can be calculated on this evaporation. If now we use any appliance whatever auxiliary to the production of steam, which consumes steam to work it, then this amount of steam must be deducted in calculating the net working efficiency of the plant. If, for example, we install a steam-jet furnace taking 10 per cent of the production of the plant, that is, 500 lb. of steam per hour, then the real net working efficiency has to be calculated on an evaporation of 4500 lb. only, since this is the amount of useful steam that passes the stop valve into the factory. This sounds so elementary as to be hardly worth mentioning, but practically every boiler test that has been carried out in the world for the last century ignores this simple fact.

In my book, Boiler Plant Testing, I have given the exact detailed figures for the performance of 400 steam boiler plants in Great Britain, representing 1513 boilers in 41 different industries, and with a total coal bill of 3,250,000 tons per annum. In these boiler plants, which are thoroughly representative of British practice, and probably also, in fact, of steam generation throughout the world, a very large amount of auxiliary steam is used for coal conveyors, ash conveyors, mechanical stokers or mechanically moving bars, steam nozzles, mechanical forced or induced draft, boiler-feed pumps, water-softening plants, driving of economizer scrapers, in the electrolytic treatment of feedwater for the prevention of corrosion, soot cleaners, and for various other purposes, so that I should estimate that the amount of steam used in cylindrical boiler-plants under average good conditions can very easily reach $12^1/_2$ per cent of the production, and in the case of water-tube boilers $4^1/_2$ per cent. The worst example is that of the use of steam nozzles, and out of the 400 plants tested, 153—that is 38 per cent—were fitted with steam nozzles, the average amount of steam consumed by these being $6^1/_2$ per cent of the production, and varying from 0.5 per cent to no less than 21.5 per cent in individual plants.

It is of course absolutely necessary to deduct this auxiliary steam in calculating the real net working efficiency of the boiler plant, but the general lack of understanding on this point is seen by the fact that we have today firms making appliances for steam generation advertising broadcast figures of tests in which 75 to 80 per cent boiler efficiency is shown, while at the same time the fact that their own appliance may be wasting from $2^1/_2$ to 20 per cent of the steam production is coolly ignored.

The A.S.M.E. Revised Code only considers this matter of sufficient importance for a footnote, and merely states that such auxiliary steam ought to be determined and a record made if it has been included in the calculations or not. There is not the slightest indication given that this question of auxiliary steam is just as important as recording the amount of coal used and water evaporated, and that without such proper record, boiler testing is worthless. As I have stated in my book, the whole question of boiler-plant testing is a most complicated one, being a combination of technical chemistry and engineering quite outside ordinary practice, and it is high time, in my opinion, that we have an International Code devised which will put the matter upon a sound and practical basis.

David Brownlie.

Manchester, England.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

The American Society of Mechanical Engineers

29 West 39th Street, New York

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Commercial Aviation in America

Howard E. Coffin

Any fair discussion of commercial aviation in our country today must of necessity consist largely of prophecies. For, to be frank, with certain notable exceptions there is little of commercial aviation worthy of consideration either as a transportation business or a production industry.

But we must not confuse frankness with pessimism. Just the same kind of statement might just as truly have been made twenty years ago with reference to the automobile business, and yet in these few years we have seen the motor-car industry achieve its present great place in the world's commercial affairs. What may not aviation, profiting by the experience of its automotive brother, be expected to do in a similar time? For here we have fulfilment of man's age-old dream, and here again the desires and needs of humanity are being served.

We are, in my own opinion, just upon the threshold of a remarkable expansion in the aeronautical-transportation art. Civilization, since the beginning of time, has never turned its back upon the newer, speedier, and more luxurious forms of locomotion and will not fail to grasp flying and develop it as an important adjunct to existing agencies of traffic and travel. The possibilities so far overshadow the problems that a successful commercial development of considerable magnitude seems beyond question.

A consideration of the many things to be done before we can expect aviation to become a dividend-paying agency in the commercial service is important. Listed in the order of pressing need they are:

First, control. An authoritative federal agency must be established by legislative action and charged with the regulation, encouragement, and control of air navigation. Federal inspection of all ships for airworthiness must be provided. All pilots and mechanics must be examined and licensed. A bureau for such work in the Department of Commerce is proposed in the Wadsworth-Hicks Bill now before Congress. The enactment of such legislation is essentially fundamental to any healthy growth of our aviation art.

Second, public confidence. Stunting at the county fairs, deviltries, and flights in poorly constructed and uninspected planes or by inexperienced pilots have occasioned far too many crashes. These accidents, emblazoned upon the front pages of our newspapers in the most sensational manner, have firmly instilled in the public mind the idea that all aviation is dangerous. Not until a convincing background of safe, sane flying history has been written in American air annals, covering a period of several years, will this fear be supplanted by confidence and faith. Time, energy, and skill expended in engineering achievement and in safeguarding air performance will slowly but surely overcome this handicap.

Third, governmental coöperation. Our nation, as a whole, is vitally concerned that commercial aviation shall progress rapidly. For such development constitutes an essential and fundamental basis upon which rest all plans for the future military-naval defense of our country. Perhaps the greatest single need of the moment is the adoption by our Government of a definite, comprehensive, and continuing program for the encouragement of our American aeronautical progress.

To illustrate, no direct subsidy is needed, but there is essential that same federal coöperation and assistance that is given our water-borne agencies of commerce. The Government has for many years indirectly subsidized shipping by the provision of ports, the charting of sea routes, the maintenance of bureaus for the disseminating of weather forecasts or meteorological data, the coast guard, the lighthouse service, and many other aids to water navigation. For our railroads there have been land grants and concessions, rights of condemnation, and elaborate federal bureaus governing labor and rates. The same kind of general aid must be extended aviation in the provision and maintenance of landing fields, wireless and radio signaling stations, beacon lighthouses for night flying, in scientific research, the charting of air routes, a code of air regulations, and in many other practical details.

Fourth, laws. Today the only law governing aviation in America is Newton's law of gravity. Forty countries have national air laws regulating the operation of civilian aircraft, designed specifically to encourage and regulate aviation as well as to eliminate flying accidents through reckless piloting or the operation of unsafe machines. Twenty-six nations have ratified the International Air Convention drawn in Paris in 1919. The United States of America is not among either class but is listed with Abyssinia, Persia, Bhutan, Nepal and Oman as countries which are not yet sufficiently forward-looking to enact legislation safeguarding life and property in air commerce.

The four needs enumerated are paramount. There are many other items in the catalog of aviation's requirements which can be met when time and experience permit. But, for the enthusiast of today, these four are immediately pressing and afford ample objective toward which our initiative and energy may be directed.

To aid in the settlement of these questions of commercial aviation, as well as to lend a hand in military and naval preparedness in the air, a new national body has recently come into being—the National Aeronautic Association. Born of the desire among thousands of our citizens for a channel of expression on aviation affairs, representative of every section of the country and of every element of our population, wholly without selfish ends, this association fills a well-recognized need and its formation marks one of the brightest spots in American aeronautic annals.

We have had for some time the Aeronautical Chamber of Commerce, representing the manufacturer and the operator; we have had the Society of Automotive Engineers, representing the designer and the inventor; and now we have that essential third member of the triangle, the National Aeronautic Association, representing the people themselves.

Thus, the picture is not empty of accomplishment. Even though we are in the infancy of commercial aviation, we have achievements to our credit of which we may well be proud. America holds all principal air records of the world: speed, endurance, altitude, long distance, all of which stand to the credit of American engineers, designers, pilots, and mechanics.

We have in the phenomenal performance of our transcontinental Air Mail the world's greatest application of commercial aviation. Every day except Sundays and holidays this service covers a round trip of 5360 miles, an annual flying schedule of 1,800,000 miles. From July 16, 1921 until September 7, 1922, this service flew ap-

proximately 2,000,000 miles without a fatal accident. During the fiscal year ending June 30, 1922, an efficiency of 94.39 per cent was maintained. That is, during that year out of every 100 trips scheduled, 94.39 were finished on schedule time. And remember that this route crosses three mountain ranges, the Alleghanies, the Rockies, and the Sierras.

Of almost equal importance has been the record of the Aeromarine Airways Company, specializing in passenger transportation. During the past three years this company has flown more than 1,000,000 miles, carrying more than 15,000 passengers and without a single mishap. It is only by an actual showing or promises performed that the public confidence can be gained and retained, and the wonderful records being made by the Air Mail Service and the few commercial companies operating are doing much toward this end.

We may well be optimistic. For, with all these records of achievment to the credit of our air industry, and with a strong national patriotic body dedicated to the furtherance of this new transportation art, it lies easily within our hands to put "America First" among the world's air powers.

Let's do it.

Howard E. Coffin.[1]

The A.S.M.E. Annual Meeting and the Power Exposition

THE holding of the first National Exposition of Power and Mechanical Engineering following the recent Annual Meeting of The American Society of Mechanical Engineers resulted in an instructive combination that should do much to inspire the members of the A.S.M.E. The meeting with its broad, diversified program and well-balanced sessions established a new precedent, and its supplement this year with a technical exhibit added an element of appeal that will be strengthened as the scope of the Exposition grows.

The Committee on Meetings and Program is somewhat concerned about the intensity of the past meeting with its twenty-four professional meetings, four entertainments and several excursions and industrial visits. Under the present conditions of great activity and diversity of members' interest it cannot be relieved, and the Committee must rely on its ability to arrange a program with the least amount of conflict between sessions with related papers. The problem will grow more severe as the Professional Divisions of the Society increase in activity. However, wealth of material for meeting programs is an embarrassment to be welcomed and one that can be overcome by the provision of more meetings or the diversion of material to regional meetings.

Notwithstanding the intensity of the Annual Meeting program, members have asked that the Power Exposition be arranged to parallel the meeting rather than follow it so that those from a distance may have more time to attend the meeting sessions they desire and also to spend the necessary amount of time at the Exposition. The Committee on Meetings and Program is giving consideration to this arrangement which is desirable and seems practical. The increase over last year in the number of out-of-town members who registered at the meeting this year is one reason why careful thought should be directed to the parallel plan.

The announcement that the Power Exposition will be continued next year will be greeted with pleasure by those who visited the Grand Central Palace this year and enjoyed the collection of latest devices, the mass of instructive data, the complete program of interesting educational moving pictures and the remarkable opportunity for broadening acquaintances. Although some important classes of power-plant equipment were not thoroughly represented, and it is hoped this omission will be corrected as the Exposition becomes established; the general character of the exhibits was excellent and every one who visited the Show carried away some ideas.

One important function of the Exposition must not be neglected. It is visited by many individuals who may not be informed about the problems of generating, distributing, and using power. In fact only a small percentage of people do understand the variety and severity of the engineering phases of the power problem. As Dean Kimball pointed out in his presidential address, the engineer has a grave responsibility in maintaining civilization. A more general appreciation will assist the engineer in shouldering this responsibility, and an exhibit such as this will assist greatly in extending general knowledge if the coöperation of the exhibitors is secured.

[1] President, National Aeronautic Association.

Improvements in The Engineering Index

THE Committee on Publication and Papers takes great pleasure in announcing two changes in The Engineering Index which it is hoped will greatly increase its service value to the readers of Mechanical Engineering. One of these is the placing of the Index items on one side of the sheet only so that items may be clipped, and the second is the addition of one page of items from technical journals received up to three days before going to press.

The Committee has been encouraged in making these changes by the increased demands on the Library for information, especially about articles from the current technical press. These requests come not only from research organizations but from individuals who are anxious to broaden their knowledge and who rely on The Engineering Index as their guide to the many excellent publications in the engineering field. This increased demand is also an encouraging symptom, indicating that the engineering public is becoming appreciative of the sources of recorded experience. For a long time we have felt that engineering libraries were not appreciated or used as widely as they should be by engineers, but the increase in use of the Index is an encouraging indication.

Perhaps a word should be said in explanation of the page of late items. The operation of setting the main portion of the monthly Engineering Index in type is laborious and requires painstaking proof reading. It is desirable to get this completed before the remainder of the text pages is ready and the Index is therefore closed a considerable time before the date of mailing. The inclusion of late items on a separate page will thus bring the Index more nearly up to date.

The Engineering Index must of necessity be selective, as the inclusion of all articles in all technical publications is obviously impossible. The annual volume of The Engineering Index includes all items that have been indexed from the publications that come to the Engineering Societies Library, but Mechanical Engineering contains only those of particular interest to mechanical engineers.

Engineers from Egypt and Czechoslovakia Study American Methods

ILLUSTRATIVE of the growing recognition of the internationality of engineering is the mission of ten graduates of the engineering schools of Egypt who have been sent to America by the Egyptian Government to study manufacturing methods in this country. Their expenses during the two years that they will remain here will be paid by the Egyptian Government. They have been placed in various factories by the Department of Commerce and will work as employees while they are acquiring a knowledge of American methods and machine-shop equipment. Subjects which will be studied by them are interchangeable manufacturing, railroad transportation, telephone systems, marine engineering, and internal-combustion-engine construction.

A young Czechoslovakian engineer is in this country on a similar mission in regard to the building trades. Through the aid of the Czechoslovakian Minister and the General Contractors' Association he will be enabled to obtain a thorough acquaintance with methods, equipment, and material used in construction in this country.

Undoubtedly these young engineers will have great influence upon the industries of their native countries in the near future. It is to be expected also that the introduction of American methods will increase the demand for American tools and equipment. But farther reaching still are the benefits accruing both to them and to us by the personal contacts thus established between members of the profession in those countries and in the United States.

The Monroe Palace—Administration Building of the

Brazilian Centennial Exposition, Opened in September, 1922

Calvin W. Rice Reports on South American Trip

Envoy to International Engineering Congress in Brazil Visited Eight Pan-American Countries—Standardization Work Pledged by Resident U. S. Engineers

YOUR Secretary sailed from New York for Rio de Janeiro on August 24 on the S. S. *Pan America*, the United States Shipping Board boat which carried the Secretary of State, Mr. Hughes, and his party to the Brazilian Centennial Exposition. I sailed as the official representative of The American Society of Mechanical Engineers and the other principal engineering societies of the United States and Canada, to the International Engineering Congress at Rio de Janeiro scheduled for September 17 to 30, and as the representative to the Brazilian Centennial Exposition of several civic bodies and of President D'Olier of the Sesquicentennial Exposition Association of Philadelphia of 1926.

When advised of my appointment, I saw an opportunity to link up membership on one of the sub-committees of the Inter-American High Commission with my relationship to the Engineering Congress and possible visits to associations of engineers in the several South American countries. Convinced of the beneficial results that might arise from such contacts, Herbert Hoover and Dr. L. S. Rowe, respectively president and secretary-general of the Commission, gave me letters to the corresponding officials of the Section of the Commission in all the South American countries I was to visit. Inasmuch as standardization of product in each country will promote the welfare of that country from both an industrial and commercial viewpoint, Mr. Hoover wrote me that—

> If his Excellency, the Minister of Finance,[1] finds it possible to hold a meeting of his Section of the Inter-American High Commission, I trust that it will be possible for you to discuss with some of the members the problem of standardization.

At that time, in all of South and Central America there was no such thing as a standardization committee or bureau. The need for work in this direction had long been apparent. This gave me a practical message to take to associations of both native engineers and members of United States and Canadian Societies in the countries I was to visit, for they, with their special training, could render a great service in such a work to the countries of their adoption.

With this in mind I purposely booked passage on the *Pan America*, for, knowing Secretary Hughes' personal admiration for Mr. Hoover, I wished to obtain, if possible, the official interest and support of the Secretary of State for Mr. Hoover's message. In several interviews on board ship I found Mr. Hughes enthusiastic over this particular activity of the Inter-American High Commission. He gave most helpful advice as to the method of presentation. He further gave his support in every way, and when I later presented my program to officials and engineering organizations I was able to say freely that it had the whole-hearted approval of our Secretary of State.

The high place which the engineer holds in South American affairs is indicated by the fact that outside of the government, the Club de Engenharia of Rio de Janeiro was the only organization that presented Secretary Hughes with an address during his first visit to Brazil. Mr. Hughes' recognition of the high place the engineer is to hold in world development is seen in his epoch-making address delivered at the dedication of the site of the monument which the United States is to give to Brazil. He said:

> The resources of science are marshaled under efficient direction to meet the peculiar increasing needs of civic life. . . . . But this fortunate land of Brazil is one of constant revelations and today more than ever before we are appreciating the limitless possibilities of its development, of the prosperity the future has in store for its people, and the extraordinary promise of their service to humanity. . . . . The various organizations now gathering here remind us that science has no frontiers. . . . . . . We have also gathered here the engineers for whose precise knowledge and trained hands Nature has long been waiting.

I arrived at Rio de Janeiro on September 5. The two weeks between that date and the opening of the Congress were spent by United States engineers in Rio in daily meetings to coöperate with the Club de Engenharia under whose auspices the Congress was being held. Our meetings, while not official in character, were a

[1] In every country but ours, the Minister of Finance is Ex-Officio Chairman of the Inter-American High Commission of his country. This work in the United States was transferred from the Treasury Department to the Department of Commerce after Mr. Hoover became Secretary of the Department of Commerce.

great aid in preparing for the Congress. Most of the papers that made up the program, lantern slides, and several motion-picture films on industrial matters were coming from the United States, and much patient and discouraging work was done in getting everything through the red tape at customs and ready for the meetings.

At a formal afternoon reception the Board of Management of the Club de Engenharia received my credentials together with those of Verne L. Havens, Editor of *Ingenieria Internacional* and delegate of the American Society of Civil Engineers. At another reception credentials were received from A. W. K. Billings, F. H. Shepard, and Dr. T. T. Read, representing civil, electrical and mining engineers.

The Congress itself was formally opened on Sunday evening, September 17. Dr. Pires do Rio, Honorary President of the Congress, who made the opening address, is Minister of Public Works and one of the most influential men of Brazil. He said in part:

> The word "engineer," builder of engines or machinery, as defined by the dictionaries, has actually a large significance in view of the magnificent industrial movement caused by the invention of the steam engine and its application to the industries of transportation and manufacture. . . . . The new industrial civilization, characterized by the use of the steam engine as a prime mover, and steel machinery as the instrument of operation, crowded the years of the last century with such a procession of important events that all that has gone before the Watt steam engine appears to be of but petty importance. . . . . . . The engineering profession responded to the call of this new state of industrial activity, and engineers ceased to be merely military officers, entrusted with the management of the crude machinery of warfare. They have become men of high technical education, accustomed to directing the work of exploitation of mines for the recovery of minerals, to designing and constructing blast furnaces, building railroads, laying pipe lines which supply cities with water and protect them from floods, and finally, to designing and building electrical machinery in all its modifications of shape and construction.

The address of Dr. do Rio was one of the high spots of the Congress. A brilliant banquet at the Jockey Club was given later in his honor and that of the officers of both the Congress and the Club de Engenharia, by engineers from the United States. It was an occasion which cemented the friendship of the engineers of the two continents.

Sessions of the Congress continued through October. The South American Railway Congress was scheduled to meet at the same time and place, and in order to avoid conflict the International Congress postponed some of its sessions so that it did not close on September 30 as had originally been planned. The attendance was not large. It consisted mainly of local engineers with a few from Chile, Argentine, and Peru. There were eight sections holding meetings. Four of these had for their presidents engineers from the United States. A fifth section had a United States engineer for its secretary. The sections and their presidents were:

1 Overland, Maritime, Fluvial and Aerial Transportation. The Pan-American Railway. Practical Means for Its Construction. (*President*, Dr. Santiago Vicuna)

2 Iron Metallurgy. (*President*, Col. C. H. Crawford)

3 Fuels. (*President*, Dr. Heitor Escardo)

4 Hydraulic Power, Its Utilization as Motive Power. (*President*, A. W. K. Billings)

5 Sanitation, Dams, and Irrigation. (*President*, Dr. Francisco Saturnino de Brito)

6 Maritime and Fluvial Ports. (*President*, Calvin W. Rice)

7 Machinery for Agricultural and Industrial Purposes. (*President*, Dr. Barbosa Goncelves)

8 Standardizing of Statistical Methods in Ports and Railways. (*President*, Verne L. Havens)

The actual accomplishments of the Congress are shown in three resolutions which were passed. The first was one to effect a permanent organization to carry out the resolutions of the Congress. The second recommended legislation in every Pan-American country to establish a standardization bureau as suggested by Mr. Hoover. The third was a resolution to call a meeting of the nations to develop the dream of the Transcontinental Railway. Minor C. Keith, of Costa Rica, the only living member of the committee which originally recommended the building of this railway, has been asked to call this meeting to order.

A specific piece of standardization work has already been undertaken by a group of United States engineers in South America who have pledged themselves to develop a list of all technical words and phrases used in Portuguese. As neither Spain nor Portugal has ever developed a technical vocabulary, technical words and phrases often have different meanings in different localities. Mr. Havens, as a representative of the McGraw-Hill Publishing Co., promised to publish this commendable work when it is completed. It is quite possible that a similar vocabulary of Spanish words and phrases will be compiled later.

As to the Exposition, I attended the opening session as the representative of civic bodies and of President D'Olier. However, the Exposition was not in readiness and had been postponed until December. As a personal representative of Mr. D'Olier and of the Societies, including the Engineers' Club, of Philadelphia, I gave a formal invitation to South American engineers to attend and participate in the International Engineering Congress to be held in Philadelphia in 1926. I was a guest at several receptions in connection with the Centennial Exposition, and certain others given in Mr. Hughes' honor. No one knows better how to entertain than our South American neighbors. The two largest receptions I attended, one given by the President of Brazil in the Catette Palace and the other given in the Itamaraty Palace by the Minister of Foreign Affairs, excelled in setting and magnificence anything ever given in the United States and remind one of the court functions of Europe.

I left Brazil on September 28, and between that time and my return to the United States on November 13, I visited Uruguay, Argentina, Chile, Peru, Panama, Costa Rica, and Cuba. In each country I had a uniform method of approach. I called first at the American Legation. The next step was to call upon the president of the local engineering society, and with him I then called upon the members of the Inter-American High Commission with

Interior View of the Jockey Club of Buenos Aires

my letters from Mr. Hoover and Dr. Rowe. In each country I urged—

1 That every professional man from the United States affiliate with the local engineering society of the country where he is residing, even if only temporarily;

2 That they form within or under the auspices of the local society groups of members of the National Engineering Societies of the United States for purposes of service to the local society;

3 That the local society link up with its government;

4 That the organization of engineers—members of U. S. Societies—link up—

a With their country's government through the embassy and commercial attaché and with the Inter-American High Commission;

b With the National Engineering Societies of the United States.

This, briefly, is the program suggested, and in several countries I was able to bring engineering organizations together with their governments for the first time. But in one country at least they are ahead of us in such matters: I refer to Cuba. If you will examine the census of Cuba for 1919 you will find that the National Board of the Census consists of three members, one chosen by the Civil Division of the Supreme Court, one by the Council of the University of Havana, and the third, an engineer chosen by the general council of the Cuban Society of Engineers. Furthermore, a law was passed in Cuba in October last providing for a commission of three to investigate Cuba's outstanding indebtedness, and this commission is to be similarly chosen: one by the Supreme Court, one by the Minister of Finance, and the third an engineer chosen by the Cuban Society of Engineers. Such participation in national affairs is an ideal toward which we may all strive.

In all the Pan-American countries I was impressed by the high regard with which the people hold those in the engineering profession. In all South America they are addressed as "Doctor" and are correspondingly respected. A man aspiring to a public career finds that an engineering education and training best fits one for political positions of responsibility and honor. Further, a South American is a world citizen with a keen grasp on international affairs. The newspapers of South America devote much space—especially preferred-position space—to international news and discussions, and murders and divorces are relegated to unimportant positions if published at all.

Without a single exception in my three months' travel of 15,000 miles everything was characterized by infinite patience and courtesy. So marked are these traits that it is essential that our official and commercial representatives to these countries have these qualifications and instincts. The ideals of our people are not truly represented if our representatives lack these qualifications.

The work of furthering international good feeling between our nation and the Pan-American countries will have the aggressive support of the South American engineer. The results of the International Engineering Congress are a foundation on which effective, permanent work may be built. Nothing less than a program devoted to the public good will form a basis for future work acceptable to the ideals of the engineers of the two continents.

Calvin W. Rice, *Secretary,*
The American Society of Mechanical Engineers

Engineer Heads Italian Embassy

Prince Gelasio Caetani, an engineer of international reputation and a member of one of the oldest families of Europe, has been appointed Italian Ambassador at Washington. He succeeds Senator Ricci who resigned when the Fascisti came into power.

The new Ambassador is a graduate of the School of Mines of Columbia University, class of 1903. Following his graduation he went West where he worked his way in true American fashion as miner, trammer, timberman and millhand. He later opened offices in San Francisco as a consulting engineer and became a member of the firm of Burch, Caetani and Hershey. The World War found Caetani still in this country but he returned to Italy immediately and became a Captain in the Engineer Corps.

The War record of Prince Gelasio is an enviable one. He was advanced to the rank of Colonel and three times decorated for bravery. It was Caetani who laid the mine that, with a single blast, blew up the whole top of the Col di Lana which destroyed an Austrian fort and opened the way for the Italian Army through the Cordevole Pass in the Upper Trentino. This feat was made possible by the practical experience which he had acquired in engineering studies in the United States. To accomplish it he designed a gallery under the fort nearly 2000 feet long.

After the war Prince Gelasio returned to the vast estates of the Caetani family near Rome where he combined a life of politics and business. He was one of the first of the Roman aristocracy to enter the political fight against socialism and communism. He became actively affiliated with the Nationalist Party when it was decidedly the unusual and unpopular thing for a man of his rank to do so. In December, 1920, Prince Gelasio enrolled himself among the original ninety Fascisti organized as a Roman cohort. At the last electoral campaign he was chosen a Deputy on the Nationalist ticket. He now comes to Washington as the first representative of the Mussolini Government there.

Underwood & Underwood
Prince Gelasio Caetani

The choice of Prince Gelasio Caetani to this important post is indeed a happy one. He is a true representative of the Italian people. The finest of Roman blood and traditions belong to him by inheritance; the right to represent Italy he has earned by personal service to her. For a thousand years the Caetani family has been closely identified with the history of the Eternal City. It has given several Popes and a number of Cardinals to the Holy See. The grandfather of Prince Gelasio, the thirteenth Duke of Sermoneta was a bitter enemy of the church and took an active part in bringing about the fall of the temporal power of Pope Pius IX.

Caetani himself has devoted his efforts since leaving the army to the stabilization of his war-stricken country in its dangerous period of reconstruction. Unemployment became a terrific problem. Communistic ideas took root and grew rapidly. For at least six centuries the Caetani family had owned a large part of the Pontine Marshes, celebrated in literature by Pliny the Younger. The land was unproductive. A low-lying lake with no outlet had over-flowed for centuries making marsh land that was of no commercial value. Returning from military life, Prince Gelasio planned and soon began the construction of a canal leading from Lake Caprolace to the Mediterranean. This mammoth undertaking, completed in 1920, reclaimed hundreds of acres of land for Italy. It was a big step in the solution of Italy's food and unemployment problems.

Although Ceatani is but in his forty-sixth year his wide experiences admirably fit him for the important post for which he has been chosen. He considers America his second home and his many friends here, who think of him just as "Gelasio Caetani," know that he is a personage as well as a Prince, a man who comes to Washington with a trained scientific mind and an understanding of the two countries whose immediate future relations lie largely in his hands.

Caetani is a member of the American Institute of Mining and Metallurgical Engineers. His friends in the National Engineering Societies are planning a dinner in his honor after his arrival in this country and the presentation of his credentials in Washington.

News of The Federated American Engineering Societies

National Board of Jurisdictional Awards

SPEAKING at a session of the A.S.M.E. Annual Meeting on December 6, L. W. Wallace, secretary of the F.A.E.S. characterized the activities of the National Board of Jurisdictional Awards as one of the most important and far-reaching pieces of work in which the Federation is engaged. Rudolph P. Miller, who is the representative of American Engineering Council on this Board, later addressed the membership on the organization, the activities, and the value to the nation of the Board. His chief purpose was to acquaint the engineers present with the salient facts concerning the organization, for despite the fact that it has been in existence since March, 1919, and has arbitrated a large number of jurisdictional strikes, comparatively few of the engineering profession appreciate or are even aware of its great influence on the building industry. Mr. Miller's address, together with supplementary details, is presented in the following paragraphs.

Practically since building-trades unions have been organized there have been from time to time disputes as to which group of mechanics should do certain work in connection with building construction. The development of asphalt shingles or strip shingles for roofing purposes, for instance, has been the cause of dispute as to whether such shingles shall be placed by the carpenter, whose jurisdiction over wooden shingles has never been questioned, or by the roofer, who has jurisdiction over other forms of roofing. Such disputes lead to strikes on building operations and the losses incidental to them fall directly on the mechanics and contractors, indirectly on the owner who must foot these bills, and ultimately on the general public.

The waste in industry due to such jurisdictional strikes has been estimated to run into millions of dollars. E. J. Russell, vice-president of the American Institute of Architects, and chairman of the Board, estimates that previous to the establishment of the Jurisdictional Board the cost of building operations was increased from seven to eight per cent unnecessarily because of jurisdictional strikes.

These considerations prompted the calling of conferences, about four years ago, of representatives from the American Institute of Architects, Engineering Council, the Building Trades Department of the American Federation of Labor, the Associated General Contractors of America, the National Building Trades Employers' Association, and the National Association of Builders' Exchanges. The purpose of these conferences was to organize a board to which jurisdiction in the building industry might be referred. It was a momentous step that was taken when these participating organizations voluntarily agreed to organize such a body and to accept and abide by its decisions.

The Board as now organized consists of eight members, one representative of the American Institute of Architects, one of the F.A.E.S., three representatives of the contractors' organizations, and three of the Building Trades Department of the A. F. of L. It is felt that such an organization is fairly representative of the building industry at large for the purpose of settling jurisdictional disputes.

Mr. Russell, who is an architect of St.Louis and the representative of the American Institute of Architects, has been the chairman of the Board ever since its formal organization in August, 1919. William J. Spencer, secretary of the Building Trades Department, A. F. of L., has been its secretary.

Complaints with regard to jurisdiction to be considered by the Board must be submitted in writing through the officials of one of the organizations that are parties to the agreement. A brief statement with regard to the complaint is forwarded to those who are immediately interested in the matter, and a time is set for the hearing of the case. Not only are the unions immediately affected given an opportunity each to present its claims and arguments, but frequently manufacturers and contractors who have an interest in the controversy are invited to present facts and evidence that they may wish to submit. For instance, in the dispute between the elevator constructors and the electrical workers over electrical work on elevators, the elevator manufacturers were given an opportunity to present their views. In that case the Board, in its endeavor to master the situation fully, went so far as to invite an elevator expert who had no interest in the dispute to give testimony on the technical questions involved.

Cases have also arisen where the manufacturers in offering a new material in building construction found difficulty in marketing their product because the mechanics of different unions claimed jurisdiction over the placing of that material, and architects hesitated to specify it for fear of starting a strike on the building. Such a case was that of Bestwall plaster board, in which case the matter was brought to the attention of the Jurisdictional Board through American Engineering Council.

A two-thirds vote of those members entitled to vote is required to render an award in all cases. That means ordinarily six votes are required. But according to the constitution, a member of the Board is not entitled to vote or to participate in discussion in executive session when the decision is fixed if he is immediately interested in the result of the controversy. In such cases provision is made for the appointment of an umpire whose decision shall be final.

Since its organization the Board has had about four meetings a year. It has rendered thirty-eight decisions, including fourteen confirmations of agreements that had been entered into some time previous to being presented to the Board, or that were the result of a suggestion in the course of a hearing. Generally a controversy was between two unions, but in six cases, three unions appeared as claimants for the same work, and in one instance four unions were involved in the dispute. Of the seventeen unions that constituted the Building Trades Department when the Jurisdictional Board was first established, thirteen have appeared as claimants before the Board.

Mr. Miller enumerated these unions, which include plumbers and steam fitters, iron workers, wood, wire and metal lathers, bricklayers and plasterers, painters, electrical workers, carpenters, roofers, sheet-metal workers, and elevator constructors, and stated that the decisions of the Board have been well observed and supported in practically all cases. The work of the Board was highly commended at the Cincinnati convention of the American Federation of Labor, in June, 1922, and at a recent meeting of the Executive Council of the A. F. of L. a resolution was passed condemning the jurisdictional strike and threatening drastic action against such unions as refused to join in any movement to avoid such strikes.

Mr. Miller felt that engineers and architects in many cases failed to support the work of the Board through lack of knowledge of its existence. What they are more especially asked to do in support of this movement was expressed in the resolution of the Board at a meeting in March, 1922, as follows:

Resolved, That the members in the American Institute of architects and The Federated American Engineering Societies insert in all specifications and contracts for building operations a stipulation that the decisions of the Jurisdictional Board shall be observed.

Mr. Miller cited a number of cases in which the decisions of arbitrary bodies have been upheld by the courts and stated that he believes that such decisions indicate that the courts would heartily support any movement, such as the work of the Jurisdictional Board, that would tend to eliminate dispute and trouble.

Referring again to the extra expense of building operations because of jurisdictional strikes, Mr. Miller stated that while it is practically impossible to get definite figures, an estimate made by Mr. Russell places the present cost at about-one-half of one per cent of the total.

Topographical Mapping

AMONG the important questions which will be discussed at the annual meeting of the American Engineering Council to be held at the Cosmos Club, Washington, D. C., January 11 and 12, is that of topographic mapping. Secretary Wallace, at the Business Meeting of the A.S.M.E., said that topographic maps of only about 34 per cent of the area of the United States have been completed. At the present rate of progress it will take from 80 to 100 years to complete the topographical survey of the country and the production of the necessary maps.

Realizing the pressing need for such maps, the Federation will give its active support toward the passage of the Temple Bill which provides a plan whereby the work may be completed in from 20 to 25 years. Efforts will be made to have this bill brought up for hearing in the near future. Meanwhile the state administrative committees of the F.A.E.S. are coöperating with the state geologists throughout the country in an educational campaign on this subject. Information is being assembled as to the progress of topographical work in the various states and existing and proposed legislation thereon so that senators and congressmen may know the respective requirements of their states.

The necessity for such maps is said to be just as pressing in the East as in the South and West. They are essential to highway and railway construction, to the location of barge canals, feeders and reservoirs, to flood control, hydroelectric development, and to land drainage, which latter affects not only the productivity of the land but also, through problems of municipal water supply and sewage disposal, the health of the nation.

Government reorganization, the Muscle Shoals investigation, letting of Government contracts, flood control, elimination of waste, and the 12-hr. shift in industry, together with other matters which have been part of the F.A.E.S. program during the past year, will be reported upon at the Annual Meeting.

Code for Identification of Piping Systems

IDENTIFICATION of fluids carried by pipes has in the past engaged the attention of many managers of industrial plants and superintendents of power stations. Five systems of color identification were published in the July, 1921, issue of MECHANICAL ENGINEERING. One of these systems had been developed by a Special Committee of The American Society of Mechanical Engineers.

We can now report that the Sectional Committee there announced has completed its organization with twenty-six members who represent twenty-four organizations. A. S. Hebble, the representative of the Society of Naval Architects and Marine Engineers, was elected chairman of the Sectional Committee at its first meeting held June 14, 1922, and I. G. Hoagland, the representative of the National Automatic Sprinkler Association, was elected secretary. The principal business of the organization meeting after the election of officers was the appointment of the Plan and Scope Committee.

This Committee was headed by W. S. Morrison as chairman and consisted of E. J. Cole, Crosby Field, W. J. Venning, H. P. Weaver, W. S. Morrison, A. S. Hebble, and I. G. Hoagland. It held a series of meetings during the summer and early fall and on November 10 presented a very carefully prepared report to the Sectional Committee. After a very thorough discussion the report on Plan and Scope was unanimously adopted with a very few minor changes. An abstract of this report is given below.

PART I

General Limitations of Plan and Scope

The plan and scope of the Sectional Committee on Code for Identification of Piping Systems shall be confined to the code of identification of piping systems in industrial and power plants, not including pipes buried in the ground

Definitions

Piping systems for the purpose of this code, in addition to pipes of any kind, shall include fittings, valves, and pipe coverings. Note that there shall be specifically excluded therefrom supports, brackets, or other accessories. Note also that the definition of pipes shall be hollow conduits for the transport of gases, liquids, semi-liquids or plastics, but does not include solids, as pipes carrying solids are more properly believed to come under the general classification of conveyors. Note also, that electric conduits are specifically excluded.

By "power plant" is meant any plant producing any of the following substances: steam, gas for heating or lighting purposes, electricity, compressed air, vacuum, water pumping, refrigeration and ice, air conditioning; but specifically not plants for the production of various chemicals or in which operations are performed for other purposes than the transfer of units of heat from one form into another more readily usable form. Note that "power plants" specifically includes heating plants.

Identification

It is obvious that to attempt to outline a code in which every product liable to be transported would have its identification, would result in a system so comprehensive that even should the supply of colors and identification symbols hold out, adoption of it would be automatically rendered impossible in those industries which do not have a major group of colors allocated to its products. It is found, however, upon investigation, that any materials transported in pipes in a plant fall in one of the following classifications:

(a) *Safe Products.* This represents a majority of the products that are handled through a plant. These products may be defined as having no hazard in their handling and no extraordinarily high value, so that a workman in approaching a piping system to make repairs will run no undue hazard in breaking into a pipe bearing a safe material, even though that material had not been emptied by previous arrangement.

(b) *Extra Valuable Material.* This might be classified as a part of the safe materials above mentioned, but inasmuch as cases came to your committee's attention where those products would have a very high value, it appeared preferable to give them a separate major classification.

(c) *Dangerous Materials.* These materials are those which inherently in themselves are hazardous to life or property by virtue of being easily flammable or productive of poisonous gases or are in themselves poisonous. They include of course materials that are known ordinarily as fire producers and explosives.

(d) *Protective Materials.* Under this class fall materials which are piped through plants for the express purposes of being available to prevent or minimize the hazard of the dangerous materials above mentioned. Thus, a plant may have certain special gases which are antidotes to poison fumes, which gases are piped through their plants for the express purpose of opening or breaking the pipe in cases of danger.

(e) *Fire-Control Equipment.* This might properly be called a division of the Protective Materials just mentioned above, though the hazard of fire and the use of sprinkler systems and other fire-fighting equipment having become so universal, it would appear better to make it a special major classification.

These five classifications, or subdivisions thereof, if necessary, in the opinion of your committee should be each given a major color, and the various subdivisions that a plant may need can be obtained by the use of numbers, names, or the like, painted in white or black upon the background of the color selected.

Machinery for Further Work

It is suggested that this work be carried on by four committees, having not over five members each, appointed by the chairman, and having the following duties:

(a) *Executive Committee.* It is felt that the size of the entire committee is so great as to render it very difficult to transact any work other than that of approving and modifying codes presented to it. It is therefore suggested that an Executive Committee be appointed to act for the Main Committee subject to its approval, and to receive the reports of the other Sub-Committees. It is recommended that the personnel of this Committee consist of the Chairman and Secretary of the Main Committee and the Chairman of each of the three Sub-Committees mentioned immediately hereinafter.

(b) *Sub-Committee on Identification by Colors.* It is felt that there should also be a sub-committee whose function it shall be to present to the Executive Committee suggestions for various colors and confirmatory evidence that those colors can be used universally. It must be here interjected that some of the members having had the largest experience in this matter have found it almost impossible to use paints when subjected to various fumes, etc. The selection of the basic colors, therefore, should be those that are most nearly resistant to the ordinary acids met with in commercial practice. It shall also be the duty of this Sub-Committee on Paints to prepare specifications for the paints selected.

(c) *Sub-Committee on Classification.* It is obvious that there are a great variety of requirements in the large number of industries to be represented and yet unless practically all industries are included prior to the issuance of the code it becomes extremely likely that certain industries will find their needs have been overlooked. It is therefore suggested that a Sub-Committee on Classification be appointed, whose function it shall be to communicate with representatives of the various industries, obtaining from each industry a list of the materials piped through their plants, classified according to the classification given under paragraph five of this report. It shall also be the duty of this Sub-Committee to combine the data received from the various industries, placing all the materials under one of the five major classifications. When these data have all been compiled, the Sub-Committee on Classification shall meet jointly with the Sub-Committee on Identification Markings Other Than Color hereinafter mentioned, for the purpose of assigning the markings selected by that Committee to the various materials under the five major classifications as compiled by this committee.

(d) *Sub-Committee on Identification Markings Other Than Color.* It is also felt that a Sub-Committee on Identification Markings Other Than Color should be appointed, whose duty it shall be to investigate the various form and shape methods of identification and make recommendation as to the most practical method of marking. Upon agreement as to the best method of identification other than color, this Sub-Committee shall meet jointly with the Sub-Committee on Classification above mentioned, for the purpose of applying definite markings to the list of materials submitted by that committee.

PART II

In this part of its report the Committee transmitted two important items of information under the heads (*a*) Number of Pipes to be Identified and (*b*) Colors.

(a) *Number of Pipes to be Identified.* It came to the Committee's notice that the number of fluids which need to be identified varies greatly in the various plants. In some only one or two are employed, in others, as many as one hundred are to be found. One chemical plant was found to have twenty-four pipes carrying gases and twenty-three liquids.

(b) *Colors.* The use of red for fire fighting or fire control appears to be

universal, and it is therefore believed that a separate classification for fire-fighting equipment should be made, and that its color should be red, which is at present accepted. In addition to the use of this color for sprinkler lines, it is believed it should be extended to include various pipe lines such as those for Firefoam, etc.

In addition to red, the experience of the members of the Committee is that the following colors are obtainable in permanent or acid-resistant form: black, green, yellow, and aluminum.

In addition to these may be mentioned the possibility of soon obtaining white, gray, and brown.

In view of these conditions and referring to the classifications in the paragraph on Identification, it is suggested that the following be the basic colors for the classification of materials given:

a Safe Products.................. Yellow
b Extra valuable materials.......... Aluminum
c Dangerous materials.............. Black
d Protective materials.............. Green
e Fire-control equipment........... Red

Complying with the provisions of the report on Plan and Scope, Chairman Hebble made the following appointments:

F. P. Ingalls or E. J. Cole, *Chairman*, Sub-Committee on Identification by Colors
Crosby Field, *Chairman*, Sub-Committee on Classification
W. S. Morrison, *Chairman*, Sub-Committee on Identification Markings Other Than Color.

Sectional Committee on Colors for Traffic Signals Organized under A.E.S.C. Procedure

THIRTY-NINE men—representing as many administrative bodies, trade associations, scientific or technical societies, and Government departments—make up the Sectional Committee on Colors for Traffic Signals which was organized at a meeting in New York City on November 9 under the auspices of the American Engineering Standards Committee.

The committee elected as its officers the following representatives of the three sponsors for the code: Chairman, Charles J. Bennett, State Highway Commissioner of Connecticut, representing the American Association of State Highway Officials; Vice-chairman, Dr. M. G. Lloyd, representing the United States Bureau of Standards; Secretary, Walter S. Paine, Research Engineer, Aetna Insurance Company, Hartford, Conn., representing the National Safety Council.

The sectional committee by resolution invited the Aeronautical Chamber of Commerce of the United States to participate in the work of the committee. It was also decided at the organization meeting of the sectional committee to appoint a sub-committee to investigate the efficiency of all color signals now in use as traffic signals, and where possible to ascertain the reasons for adopting certain colors for specific uses. This committee will investigate the use of various types of semaphores and silent policemen. Another committee will make an original study of specific colors for definite uses as a check upon previous researches and to establish certain colors for traffic signals. A third committee will study non-luminous signs and signals (excluding luminous signals) and after a thorough research propose signs of definite colors and shapes for highways and also for railroad crossings.

Automobile Headlight Testing Specifications Approved by A.E.S.C.

ONE of the tribulations of the touring motorist—the hopeless attempt to comply with the automobile headlighting regulations of all the states through which he passes on his trip across the continent—will be removed as soon as the various state motor-vehicle departments have all adopted the Specifications of Laboratory Tests for Approval of Electric Headlighting Devices for Motor Vehicles which has just been approved by the American Engineering Standards Committee.

Even before these specifications had been formally approved by the A.E.S.C., nine of the states indicated that they would adopt the specifications; in three states they are already in effect.

These specifications were submitted to the A.E.S.C. by the Illuminating Engineering Society. This organization and the Society of Automotive Engineers have been appointed joint sponsors for any revision and further development of the code which may be necessary.

NEWS OF OTHER SOCIETIES

Taylor Society

The recent meeting of the Taylor Society was a particularly practical one in that the papers presented at its sessions were chiefly descriptions of actual conditions and problems in various concerns, and that ample time was allowed for discussion on each of them.

The first of the six addresses at the convention, which was held in New York, November 23 and 24, 1922, was by Percy S. Brown, works manager of The Corona Typewriter Company, Groton, N. Y. His address dealt with a specific type of manufacture, the continuous production of portable typewriters, their cases and a few accessories, for which it has been found expedient to departmentalize highly and to standardize operations. The functions of the various departments and their relation to each other were discussed in some detail by Mr. Brown, who also told of research work to develop standard operations. The Corona Company stimulates the interest of its foremen by holding bi-monthly conferences at which the management presents information on sales costs, items of expense, and other matters not usually brought to the attention of foremen, and gives an opportunity for discussion of all major factory problems. Reduction of manufacturing costs by the study of routing operations and precise control through the planning system has been effected to a large degree in the plants of the Corona Company. The discussion upon Mr. Brown's paper was led by L. Herbert Ballou, of the Lewis Mfg. Co., Walpole, Mass., and R. H. Lansburgh, Wharton School, University of Pennsylvania.

Dr. H. S. Person, managing director of the Taylor Society, speaking at an evening session on Thursday, November 23, on Shaping Your Management to Meet Developing Industrial Conditions, reviewed conditions during the last few years and showed the effect of the recent business depression upon various enterprises. He stated as his belief that there are still many difficulties to be met, particularly by those establishments which continue to employ conventional management methods.

Dr. Person said that he did not believe that future conditions could safely be forecasted from the present industrial activity and went on to point out some of the facts which have been learned from studies of business cycles and analyses of industrial conditions. He called attention to the fact that demand is going to be less than the productive capacity and said that the way out for the successful competitor seems to be to develop an inclusive system of management which will more than compensate for high prime costs by cost savings elsewhere, thereby effecting lower factory costs and making possible lower selling prices.

Among his suggestions for the new management Dr. Person emphasized the need of more thought being given to policy and general plans and advocated that definite master plans, budgets, and schedules of operation be devised for a considerable period ahead. Organizations should have units to analyze the market and interpret industrial statistics. Improved production methods should be more generally utilized and advertising should bear on the quality of staple merchandise rather than on the creation of new wants. The coöperation of the personnel is essential and the forceful, acquisitive type of executive should be balanced by the thinking, investigating, planning type.

A session on statistical compilation was particularly welcome as many business organizations seem to find it difficult to determine what statistics are essential and what are non-essential, and to establish a statistical technique which secures results precisely and economically. Harry B. Horwitz and H. J. Hutkin, chief speakers at this session, discussed some of the uses of statistical compilation as a function of scientific management, presenting a description of the organization, methods, results, and equipment of the planning department of the statistical and methods divisions of the Joseph and Feiss Company of Cleveland, with which both are connected.

The methods of the Hood Rubber Co. and those of the Dennison Mfg. Co. in analyzing the market and establishing coördinated schedules of sales production and finance on the basis of that analysis were described by representatives of those companies, W. W. Duncan and E. E. Brooks, respectively.

Philip J. Reilly, associate director of the Retail Research Association, New York, addressed the convention on November 24 on the subject of the reduction of waste through research studies in the

operating departments of retail stores, summarizing the results of recent studies that have been made by his association.

The closing symposium dealt with the supervision of personnel. It reviewed the development of personnel departments and the elimination of many of them during the period of depression following the war, pointing out the durable features of personnel work.

American Society of Refrigerating Engineers

The eighteenth annual meeting of the American Society of Refrigerating Engineers, one session of which was held in conjunction with the A.S.M.E. Annual Meeting, took place in New York, December 4 to 6, inclusive. The opening session was devoted to a business meeting, which included discussions of the Mechanical Refrigeration Safety Code and the Code for Unfired Pressure Vessels. New officers elected at this session were William S. Shipley, Brooklyn, N. Y., president, Van R. H. Green, New York City, vice-president; L. Howard Jenks was reëlected treasurer, and William H. Ross, secretary.

The joint session with the A.S.M.E., held on the afternoon of December 4, included two papers, one on the Economic Thickness of Insulation in the Refrigerating Field, by Percy Nicholls, Pittsburgh, Pa., contributed by the A.S.R.E.; and one on the Design of Cooling Towers, by C. S. Robinson, of the Department of Chemical Engineering, Massachusetts Institute of Technology, contributed by the A.S.M.E.

Mr. Nicholls, who is connected with the Research Laboratory of the A.S.R.E., defined the economic thickness for a heat insulation as that which will reduce to a minimum the sum of the expenses due to the heat passed through it plus the expenses of prevention. He interpreted this definition for such cases as the walls of ice and storage houses, pointing out the factors of monetary expense, and also for tanks, pipes, and cylinders. Mr. Nicholls stated that it was not his purpose to recommend a definite thickness, but rather to establish a standard of reference, and to set forth a basis of argument on which the figuring of the thickness may be done.

In Mr. Robinson's paper it was pointed out that engineers have designed cooling towers in the past on empirical information and in accordance with the experience of previous successful designs. Wide departure from standard designs is difficult because of the lack of scientific basis for the design. Mr. Robinson therefore established the general principle applicable to cooling-tower design and derived equations for the use of the designer. He presented a quantity of experimental data to substantiate the validity of his formulas and showed by an actual experiment how these formulas are applicable to the design of a counter-current cooling tower.

The presidential address, delivered by Harry Sloan of Milwaukee, Wis., retiring president of the society, at an evening session, December 4, was on the subject of educating and training the engineer. Other addresses at this session were by C. S. Cragoe, of the National Bureau of Standards, Washington, D. C., giving the physical properties of ammonia as determined by that bureau, and by H. J. Macintire, Urbana, Ill., on the Flexibility of Cast-Iron Radiators for Direct Expansion of Ammonia.

Two technical sessions were held on the second day of the convention at which four papers were presented and the commercial value of hydrocarbon refrigerants was discussed. George A. Horne, of New York City, described tests made at the Tenth Avenue plant of the Merchants' Refrigerating Co., New York, to determine the horsepower for varying condenser pressures of a single-acting simple ammonia compressor, and tubular condensers. The machine on which the tests were made is a vertical three-cylinder, single-acting, simple compressor of the enclosed type with pistons 18 in. in diameter and a 20-in. stroke. The machine is direct-connected to a synchronous motor and is operated at 164 r.p.m. The condensers are shell and tube, open type, in which the water is pumped over the top and flows through the tubes by gravity into an open pan. The condenser liquid is cooled in a double-pipe liquid cooler from which it passes to a shell-and-tube brine cooler. Mr. Horne's paper contained tables giving test data, power calculations and volumetric efficiencies, condenser calculations and data, and calibrations of the ammonia meter. He called particular attention to this method of measuring the refrigerating output of the compressor, which he said was a distinct refinement over any method of simply weighing or gaging the liquid during the tests.

A paper by W. G. Croll, of Wellington, New Zealand, described the design of several air batteries installed in a plant in southern New Zealand for use in the refrigeration of meat. Desirable features of this method are clean, dry freezing rooms and purer air, and although the first cost is expensive, the power factor is high.

There were also presented at this session papers on the Compresion Refrigerating Cycle, by W. H. Motz, Chicago, Ill., and the Reliability of Fluid Meters in Refrigeration Tests, by L. S. Morse, York, Pa.

The closing technical session was held on Wednesday, December 6, and included papers entitled Heat Waste in Ammonia-Compression Refrigerating Machines, by J. H. H. Voss, New York, and An Oscillating Compressor for Ammonia, by H. J. Macintire, Urbana, Ill., together with discussions of new things in refrigeration and other topics suggested by the membership.

Inspection trips were made to the Tenth Avenue and North Moore Street plants of the American Refrigerating Company, to the Hellgate Station of the United Electric Light & Power Co., and to the Carrier Engineering Corpn., of Newark.

Society of Naval Architects and Marine Engineers

The thirtieth general meeting of the Society of Naval Architects and Marine Engineers was held in New York during American Marine Week, November 8 and 9, 1922. Twelve technical papers were presented, a number of which dealt with subjects of interest to mechanical engineers.

Elmer A. Sperry, president of the Sperry Gyroscope Co., Brooklyn, N. Y., in a paper on Automatic Steering, described the method of operation of the "iron quartermaster" and its auxiliaries. Although best results can be obtained with this instrument, an experienced quartermaster, with the aid of a gyro-compass repeater conveniently located, can obtain a high degree of accuracy in steering. Mr. Sperry also discussed steering by magnetic compass and described separate and unit systems for automatic steering.

Edwin A. Stevens, Jr., vice-president of the Hoboken Land & Improvement Co., showed the results of applying Dyson's method of analysis to propellers of ocean-going merchant vessels. Three groups of ships were considered, namely, single-screw vessels; vessels fitted with two or more screws, the wing screw being carried in struts; and vessels fitted with two or more screws, the wing screws being carried in bosses or spectacle frames.

Results of wake tests performed upon different models by means of a current meter filled with wheels of varying diameter, were given by E. M. Bragg, professor of naval architecture and marine engineering at the University of Michigan. The study showed that any complete system for determining wake values must take account of the diameter of the screw relative to the draft of the ship; the draft of the ship relative to the breadth of the ship; the fore and aft position of the screw; the transverse position of the screw; the vertical position of the screw relative to the keel; and the vertical prismatic coefficient of the ship.

In a paper entitled Some Experiments on Propeller Position and Propulsive Efficiency, Rear-Admiral David W. Taylor, U. S. N., enumerated the factors affecting hull efficiency and described experiments upon a single-screw low-speed vessel to determine the propeller position.

A. D. Stevens, naval architect and consulting engineer, Jacksonville, Fla., gave a description of how a Government sub-chaser was converted into a 1650-hp. gasoline fire boat for Jacksonville.

Prof. William Hovgaard, Massachusetts Institute of Technology, presented a paper containing a brief description of the principal features of a ship of the Zeppelin type. He also took up the problem of the calculation of stresses and compared the method of transverse shears and of bending moments, giving reasons for the superiority of the latter method.

Points to be considered in the selection of propelling machinery from the point of view of the ship owner were given by J. L. Ackerson, vice-president of the Merchant Shipbuilding Corporation, Chester, Pa. Reliability, economy in operation, and weight were the factors emphasized.

The fact that the Second Annual Marine Exposition was held in New York during the week of November 4–11 gave those attending the convention an opportunity to see the latest developments in hull construction, propulsion machinery, particularly the Diesel

engine, and safety devices, and such modern equipment as the radio direction finder, the mechanical quartermaster described in Mr. Sperry's paper on Automatic Steering, and sounding apparatus.

National Personnel Association

The first annual convention of the National Personnel Association was held at Pittsburgh, Pa., November 8–10, 1922. This association was recently formed through the merger of the National Association of Corporation Training and the Industrial Relations Association of America.

Immigration was a principal topic of the convention. The effect of existing immigration laws on labor and industry, training immigrant workers, the social and economic effects of our immigration policy, and the immigrant's point of view were subjects discussed. Among the speakers were Michael I. Pupin, professor of electromechanics, Columbia University, and Magnus W. Alexander, managing director of the National Industrial Conference Board.

The Committee on Trade Apprenticeship Progress recommended that a system for developing sufficient training courses be centralized under a national organization that would embody representatives from the manufacturing, educational, and publishing institutions, and sub-organizations to introduce and supervise the work in different sections throughout the country.

The report of the Committee on Employment and Labor Turnover emphasized the need for coöperation between employment and operating departments, and for careful consideration on the part of the management in hiring, training, and discharging employees.

The Committee on Economics for Employees reported on an investigation of methods of training in industrial economics, touching particularly on the gathering of data illustrating the economic principles as they are working out through the various jobs and every-day relationships of the employee with his job, his fellow-employees, with the firm, and with his employers.

The Committee on Shop Training, headed by R. L. Sackett, dean of engineering, Pennsylvania State College, presented a report calling attention to the shortage of skilled workmen and outlining different types of training.

Discussing the development of men for executive positions, a committee headed by C. R. Dooley, manager of personnel and training, Standard Oil Company of New Jersey, said that "companies having had training courses for several years invariably report that the effort and expense involved are justified by the results."

The report on foreman-training methods stated that foremanship training to be really effective must be a continuous process, and prophesied that the work of the next few years will be not so much the development of new methods as better application of the methods already outlined to the conditions for which they are best suited.

The Committee on Personnel Problems of Small Offices reported that the chief fact discovered "is the almost total lack of a definite, planned training program in the majority of companies. Training in small offices has been left to take care of itself."

An especially important report was that on relations with engineering colleges, prepared by a committee of which W. E. Wickenden, American Telephone & Telegraph Co., New York, is chairman. The report enumerates ways and means by which assistance, through the Personnel Association, can be rendered by industries to engineering colleges.

Reports were also heard on health education, pensions for industrial and commercial employees, employee publications, and industrial and public-school relations, industrial motion pictures, and job analyses.

Other addresses at the convention were by W. W. Kincaid, Niagara Falls, president of the Association, on Nationwide Coöperation in Personnel Work, and by E. K. Hall, vice-president of the American Telephone & Telegraph Co., on Management's Responsibility for and Opportunities in the Personnel Job.

Inspection trips were made during the convention to the East Pittsburgh works of the Westinghouse Elec. & Mfg. Co., the Duquesne works of the Carnegie Steel Co., the Colfax power plant of the Duquesne Light Co., the American Window Glass Co., Arnold, Pa., and the Mellon Institute of Industrial Research of the University of Pittsburgh.

Lincoln New Dean of Electrical Engineering School of Cornell University


Paul M. Lincoln

On November 1, 1922, Paul M. Lincoln assumed his duties as director of the electrical engineering school of Cornell University, replacing Prof. Alexander Gray who died some months ago. Since 1919 Mr. Lincoln has been associated with the Lincoln Electric Co., organized by his older brother in 1904. Mr. Lincoln was graduated in 1892 from Ohio State University with the degree of M.E. in E.E., and then entered the employ of the Short Electric Co., Cleveland, Ohio. Later he was connected with the Westinghouse Electric & Manufacturing Co., Pittsburgh, Pa., and after two and a half years with that concern became electrical superintendent of the Niagara Falls Power Co., Niagara Falls, N. Y., where he was located for seven years. In 1902 he returned to the Westinghouse Co., where for about seven years he had charge of the power division of the engineering department. In 1910 he was appointed a general engineer with the company and remained with them until 1919, when he resigned to become associated with the Lincoln Electric Co. From 1911 to 1915 Mr. Lincoln acted as head of the electrical school of the University of Pittsburgh, while still carrying on his work with the Westinghouse Co.

Mr. Lincoln is a member of both the A.S.M.E., and the A.I.E.E., and was president of the latter society in 1914. In 1902 he invented the synchroscope, for which he was awarded the John Scott Medal by the City of Philadelphia on recommendation of The Franklin Institute.

Boston Gives M.I.T. Students Unusual Opportunity

STUDENTS at the Massachusetts Institute of Technology have been given an opportunity to assist in solving some of Boston's municipal problems in a recent offer made by that city through its mayor, James M. Curley. Four prizes of $500 each will be given for the best reports and working plans for solving certain problems connected with street traffic, street cleaning, malodorous and unsanitary nuisances, and fire-protective building construction.

The competition is open to any student enrolled at M.I.T. in 1922–1923 and is to be concluded May 1, 1923. The conditions of the contest stipulate that the recipients of such prize awards relinquish full rights, without further payments, to the use of the devices or methods proposed. One judge is to be selected by the mayor, one by the head of the Department of Civil and Sanitary Engineering at the Institute, and the third by the two so selected.

Chinese Board Specifies A.S.M.E. Boilers

In a recent communication Mr. Wm. Althoff, Asst. Chief, Industrial Machinery Division of the Department of Commerce, Washington, D. C., states that the Department has received copies of specifications for tenders invited by the Min River Conservancy Board, Foochow, China, for a steam-operated river-type hydraulic dredge for improving the channel of the Min River; tenders to be in the hands of the Board not later than February 15, 1923. These specifications include the following clauses:

> *Boiler.* The boiler shall be constructed in accordance with the specifications of the Boiler Code Committee of the A.S.M.E.—or other equivalent specifications.
>
> *Hull.* The steel used in the hull shall meet the requirements of the specifications for structural steel for ships of the American Society for Testing Materials—or other equivalent specifications.

The Min River Conservancy Board, although a Chinese Government organization is, through their representation on it, under the virtual power and control of the commissioner of customs and the foreign consular representatives and representatives of foreign commercial bodies. Its funds are supplied by a surtax on the regular customs tariff and the funds are administered by the Board though collected by the customs. The engineer in chief is an American.

LIBRARY NOTES AND BOOK REVIEWS

American Malleable Cast Iron. By H. A. Schwartz. First edition. Penton Publishing Co., Cleveland, Ohio, 1922. Cloth, 6 × 9 in., 416 pp., illus., diagrams, $7.

This book, the only American one on the subject now in print, is the work of a metallurgist with long experience in the industry. The volume opens with a historical account of the development of the malleable industry in the United States from its inception in 1820. The various phases of manufacture are then discussed, including the plant, materials, fuels, refractories and melting practice with air, electric, cupola and open-hearth furnaces. Succeeding chapters treat of annealing, molding and pattern-making, cleaning, finishing, inspecting and testing. The final section of the book is a study of the physical, thermal and electrical properties of malleable castings, in which is given much hitherto unpublished material. A selected bibliography of nearly 200 references is given.

A.S.T.M. Tentative Standards. 1922. American Society for Testing Materials, Philadelphia, 1922. Cloth, 6 × 9 in., $8.

The 1922 issue of tentative standards contains 163 specifications for engineering materials, such as metals, cement, lime, gypsum and clay products, preservative coatings, petroleum products, road materials, coal and coke, waterproofing, insulating materials, containers, rubber goods and textiles. These specifications are tentative, that is, they are distributed prior to definite adoption, for the purpose of eliciting criticism.

Anthracite and the Anthracite Industry. By A. Leonard Summers. Isaac Pitman & Sons, New York, 1922. (Pitman's Common Commodities and Industries.) Cloth, 5 × 7 in., 126 pp., illus., map, $1.

A brief non-technical account of anthracite mining, and of the advantages of anthracite as a fuel, with special reference to British conditions.

Belt Conveyors and Belt Elevators. By Frederic V. Hetzel. John Wiley & Sons, New York, 1922. Cloth, 6 × 9 in., 333 pp., illus., diagrams, tables, $5.

This book, the author says, is not a mere restatement of trade literature nor a collection of descriptions of installations of conveying and elevating machinery. It aims rather to explain principles and the reasons for doing things. The present volume deals with belt conveyors and belt elevators, and uses these machines, which are so widely useful, to illustrate some of the general principles that underly the design and use of conveying and elevating machinery. The author has had thirty years' experience in the design, manufacture and erection of machinery of this kind.

Berechnen und Entwerfen von Turbinen-und Wasserkraft-Anlagen By I. Holl. Third edition. R. Oldenbourg, Munich, 1922. Paper, 7 × 10 in., 181 pp., illus., 225 mk.

Holl's Calculation and Design of Turbine and Water-Power Plants was written with the intention to furnish all who are interested in water-power plants with a convenient assistant in solving the various problems that arise in calculation and design. To facilitate calculation, the author invented a turbine slide rule, the use of which is explained in this book.

In this edition, which is thoroughly revised, the book is planned to give the designer a concise introduction to all the structural and mechanical details of water-power plants, which will not only enable him to determine the turbine system for any projected plant, but will also give information upon the construction required in connection therewith.

Dyke's Automobile and Gasoline Engine Encyclopedia. By A. L. Dyke. Thirteenth edition. Goodheart-Willcox Co., Chicago, 1922. Cloth, 7 × 10 in., 1226 pp., illus., $6.

The new edition of this well known reference and instruction book has been entirely rewritten and rearranged. The number of pages has been increased from 960 to 1238, and the illustrations from 3362 to 4143. Intended for owners, repair men and students, the book is a remarkably comprehensive,compendium of information on automobile construction, operation and repair.

Electric Power-Plant Engineering. By J. Weingreen. Third edition. McGraw-Hill Book Co., New York, 1922. Cloth, 6 × 9 in., 511 pp., illus., diagram.

Intended to provide information on practical problems connected with the control of the generation and distribution of electrical energy. Theoretical discussions are reduced to a minimum, the book being primarily a record of current American practice in power-plant engineering. This edition has been thoroughly revised. New material has been added on oil switches, open-air switches, lightning arresters and outdoor sub-stations, and reactive coils and synchronous condensers have been discussed in greater detail.

Elektrische Oefen. By Oswald Meyer. Vereinigung Wissenschaftlicher Verleger, Berlin and Leipzig, 1922. Boards, 4 × 6 in., 133 pp., illus., $0.30.

This little book opens with a short historical review of electric-heating processes. Next are discussed the physical foundations, methods of measuring furnace temperatures, structural elements and materials for electric furnaces. This is followed by a chapter devoted to the various types of furnaces, classified by methods of heating. The remaining chapters discuss the use of electric furnaces in various industries, domestic electric apparatus for heating and cooking, electric boilers, etc.

Handbook of the National District Heating Association. D. L. Gaskill, Sec'y-Treas., Greenville, 1921. Fabrikoid, 5 × 7 in., $5.

Prepared by the Educational Committee of the Association, and intended as a working manual of district-heating practice, particularly with respect to engineering problems. The material is published in loose-leaf form, arranged in two general divisions, Steam and Hot-Water Heating. Each of these divisions is subdivided into the following groups: General, Generation, Distribution, Utilization, Metering. In addition to engineering data, commercial information supplied by manufacturers of apparatus is included.

Hutte. Hilfstafeln zur I. Verwandlung von Echten Bruchen in Dezimal-Bruche, II. Zerlegung der Zahlen bis 10,000 in Primfaktoren. Third edition. Edited by the Akademischen Verein Hütte. Wilhelm Ernst & Sohn, Berlin, 1922. Paper, 5 × 8 in., 83 pp., tables, 2 mks.

Two convenient mathematical tables, for the use of calculators and designers are given in this little book. Table I is a series of common fractions arranged in an increasing series and accompanied by their decimal equivalents, calculated to eleven places. It can be used to translate any decimal fraction into a common fraction, neither term of which will be greater than 100. Table II gives the simplest factors of all numbers not divisible by 2 or 5, from 1 to 10,000 and also shows the prime numbers in this range.

The tables are intended primarily for determining gear ratios for lathes, milling machines, etc., but are adapted for other uses as well. Examples of their use for various purposes are given.

Manufacture and Uses of Abrasive Materials. By Alfred B. Searle. Isaac Pitman & Sons, New York, 1922. (Pitman's Technical Primer Series.) Cloth, 4 × 6 in., 118 pp., illus., $0.85.

Brief description of abrasive materials and their preparation and of the manufacture of abrasive wheels, papers and polishes, together with advice upon the selection and testing of abrasives, and the erection and operation of grinding machines. Should be useful to those called upon to deal with grinding problems without any very extended experience in the art.

Manufacture of Dyes. By John Cannell Cain. Macmillan & Co., New York, 1922. Cloth, 6 × 9 in., 274 pp., $4.50.

This volume seems intended as a supplement to the author's earlier work, The Manufacture of Intermediate Products for Dyes. It describes methods for making a large number of commercial dyes,

giving details of the processes and referring to the English, American, French and German patents concerned, as well as to descriptions in books and periodicals.

Theory of Wave Transmission. By George Constantinesco. Second edition, revised. Walter Haddon, London, 1922. Cloth, 5 × 9 in. 209 pp., tables, 10s. 6d.

A detailed mathematical exposition of the theory underlying the method of power transmission invented by the author. In this system energy is transmitted from one point to another by means of periodic variations of pressure which produce longitudinal wave pulsations in a column of liquid enclosed in a system of piping connecting the wave generator and the tool or machine. Many advantages are claimed for the method, which has been applied practically to rock drills and other percussive tools and to trigger control in machine guns, and is now being adapted to the production of rotary motion.

Treatise on Bessel Functions. By Andrew Gray and G. B. Mathews. Second edition. Macmillan & Co., London, 1922. Cloth, 6×9 in., 327 pp., $12.

This book has been written in view of the great and growing importance of the Bessel functions in almost every branch of mathematical physics; and its principal object is to supply in a convenient form as much of the theory of functions as is necessary for their practical application, and to illustrate their use by a selection of physical problems, worked out in some detail. This new edition has been thoroughly revised. The earlier chapters have been rewritten, examples have been appended and additions have been made to the tables. A bibliography is included.

Welding Encyclopedia. By L. B. Mackenzie and H. S. Card. Second edition. Welding Engineer Publishing Co., Chicago, 1922. Fabrikoid, 6×9 in., 388 pp., illus., tables, charts, $5.

A reference book on the theory, practice and application of the four processes for autogenous welding. The first half of the book is a dictionary of the words, terms and trade names used in the industry. Included in this are instructions for the common types of repair and production work, descriptions of tests, specifications for rods and wires, and descriptions of the application of welding in various industries. Following the dictionary are separate chapters on the four processes for welding, giving detailed descriptions of each and instructions for its use. Chapters on boiler tank, pipe and rail-joint welding are then given, followed by a section on the regulations of federal and state authorities, and insurance companies, and a chapter on the heat treatment of steel. A collection of charts and tables and a catalog section are also provided.

TESTING INVOLUTE SPUR GEARS

(Continued from page 34)

ing gears. No matter how accurately a gear may be cut, if it is carelessly forced or keyed on its shaft or if the shafts are not in line in both planes, satisfactory operation cannot be obtained.

Discussion

B. F. Waterman[1] submitted a written discussion in which he said that the reason gears had not been inspected with quite the precision employed in the case of other and simpler pieces, was because gears were not the easiest pieces of mechanism to understand and measure.

In most shops if a pair of gears was noisy it was immediately assumed that the cutter was not right or, if the cutters had cut other gears that had run quietly, that the gear-cutting machine was at fault, when it was probably neither of these but rather carelessness on the part of the operator in setting up the machine, and perhaps improper mounting of the gears or, last but the least considered, the design of the gears or the machine upon which they were finally mounted to run.

If, however, proper care was taken in using the machines and cutting tools, and means were at hand for testing the gears, much trouble could be avoided. In all up-to-date shops an effort was made to check the first pair of gears taken off the cutting machine and, if they were not correct, steps could be taken to correct the trouble in so far as the gears were concerned.

In most shops the gear-testing machine first mentioned in the paper was sufficient, as it was a very easy one to use.

The Saurer machine seemed to have considerable merit and undoubtedly would find a place in many gear shops, but it was perhaps too exacting for most gears. With gears, as with everything else used in machinery, tolerances of greater or less degree had to be employed, and in most cases they were sufficiently great to make the use of charts unnecessary.

Charles H. Logue[2] wrote that the study of irregularities in pitch-line velocities was a study of the entire gear problem, and the paper was therefore of vital importance.

It might be claimed that there was little use in locating and measuring errors in the formation of gear teeth—that what was required was a means for producing gears free from error. The fact of the matter was that there was little chance for securing the means by which more perfect gears might be produced, until the nature of the errors encountered could be located, measured and understood. This must serve as a guide in the production of better cutters and hobs, as well as in the design of the teeth themselves. Again, to attain the highest quality or to maintain any uniform quality with the means at hand, facilities must be immediately available for a measurement of quality. In all other branches of machine-shop practice this was a recognized principle: it was only in the cutting of gear teeth that this principle was ignored.

The testing machine described by Mr. Estabrook furnished a definite means by which the accumulative error of a *pair of gears* might be measured, leaving no opportunity for a difference of opinion as to relative operating quality.

The service which might be expected of a pair of gears depended primarily upon their operating quality, or upon the correctness of the formation and spacing of the teeth. The trade, sooner or later, would specify this quality and accept or reject gears on percentage of error in pitch-line velocities—that is, they would ask for a definite measure of attainment.

Earle Buckingham[3] said that an inspection had two prime purposes: First, to see that the manufacturing facilities and processes were sufficiently accurate and reliable to produce the desired results; second, to test the results actually obtained—to sort out the good work from the bad. To test the tools required a great variety of equipment, which in many cases was laboratory equipment. Any facilities for testing the product itself should be extremely simple. The so-called feeler test was an extremely good one when the man who gave it understood what he was doing; but after he had sorted the good from the bad, he knew but very little as to why the bad ones were bad. That was where the more elaborate laboratory instruments came in.

F. E. Cardullo[4] said that after a gear had been tested by all of the processes which had been described, there still remained to be dealt with gears which were noisy. He believed that a part of the noise might be attributed to the fact that in the action of the gear during the angle of approach the effect of friction between the teeth was to increase the pressure angle, but after the recess the effect was to reduce the pressure angle. That meant each time the tooth passed the center line, there would be an alteration to some extent in the amount, and to a considerable extent in the direction, of the forces acting between the teeth.

Now, if these forces, which were absolutely independent of the form of the gear, were dependent only on the smoothness of action and the quality of lubrication, fell into natural synchronism with any of the natural vibration periods of the body in which the gear was mounted, a noisy set of gears would result, no matter how perfect the forms of the teeth and all the other features might be. He believed that a great many mysterious gear troubles had been due to something of that nature. There was a very wide field still for investigation in the action that went on in a pair of running gears, and the possibilities of trouble.

[1] Designer, Brown & Sharpe Mfg. Co., Providence, R. I. Mem. Am. Soc.M.E.

[2] Consulting Engineer, Syracuse, N. Y.

[3] Engineer, Pratt & Whitney Co., Hartford, Conn. Mem. Am.Soc.M.E.

[4] Chief Engineer, G. A. Gray Co., Cincinnati, Ohio. Mem. Am.Soc.M.E.

THE ENGINEERING INDEX

(Registered United States, Great Britain and Canada)

Exigencies of publication make it necessary to put the main body of The Engineering Index (p. 137-EI of the advertising section) into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.

AIRPLANES

All-Metal. The Modern Airplane and All-Metal Construction, William B. Stout. Soc. Automotive Engrs.—Jl., vol. 11, no. 6, Dec. 1922, pp. 495–500 and (discussion) 500–504, 11 figs. Outline of structural problems followed by progress of development of thick-wing and all-metal airplanes with which author has been identified. Author believes that future commercial airplanes will have all-metal construction.

ALLOYS

Light. Some Points of Contact Between Metallurgy and Engineering, Owen W. Ellis. Eng. Jl. (Eng. Inst. of Canada), vol. 5, no. 12, Dec. 1922, pp. 576–581, 1 fig. Early development of iron and steel industry; research on alloys; economics of alloys of aluminum for structural work; composition and mechanical properties of duralumin; tests on a duralumin channel; important alloys recently investigated; possibility of use of light alloys in structural field.

AUTOMOBILE ENGINES

Moderate vs. High-Speed. The Low-Compression Low-Speed Engine for Motor Vehicles, F. Strickland, and The High-Compression High-Speed Engine for Motor Vehicles, H. R. Ricardo. Engineering, vol. 114, no. 2968, Nov. 17, 1922, pp. 627–630, 8 figs. Contributions to debate before Instn. Automobile Engrs. See also Automotive Industries, vol. 47, no. 22, Nov. 30, 1922, pp. 1079–1081.

Reciprocating Parts, Light-Weight. Advantages of Light-Weight Reciprocating Parts, L. H. Pomeroy. Soc. Automotive Engrs.—Jl. vol. 11, no. 6, Dec. 1922, pp. 508–515 and (discussion) 515–519, 1 fig. Influence of weight of reciprocating parts on chassis in general and engine in particular is emphasized as being of greater importance than actual saving in weight of parts themselves; tabulation of specific strengths of various materials used in automotive engineering shows advantages of aluminum as compared with steel; comparison of steel and aluminum connecting rods; advantages of using aluminum in connecting rod to secure stiffness.

BOILER PLANTS

Improvements. Plant Improvement Shows Large Saving. Power, vol. 56, no. 21, Nov. 21, 1922, pp. 790–794, 11 figs. Changes at plant of Int. Motor Co. made it possible for three boilers operating at 200-per cent rating to do work of eight used originally; large saving was effected by doubling evaporation per lb. of coal, resulting from change of boiler baffling and application of hand stokers. Plant, instead of consuming 50 tons of coal daily, averaged 50 tons last winter.

BOILERS

Electrically Heated. Electric Steam Boilers for Using Surplus Water Power. Elec. World, vol. 80, no. 23, Dec. 2, 1922, pp. 1211–1212, 3 figs. High efficiency, negligible attendance, small floor space and flexibility of operation claimed for electrically heated boilers; relative merits with essential requirements; three methods of heating water are available, indirect, direct and electrode system. Based on information from Hackethal Nachrichten.

CASTING

Centrifugal. Casting Steel Ingots Centrifugally, L. Cammen. Iron Age, vol. 110, no. 23, Dec. 7, 1922, pp. 1494–1496, 3 figs. Results from using horizontal bottle-neck mold; comparison with earlier attempts; excellence of ingots and their cost.

CRANES

Traveling. 100-Ton Overhead Electric Traveling Crane. Engineer, vol. 134, no. 3491, Nov. 24, 1922, p. 562, 3 figs. partly on p. 554. Four-motor electric crane, capable of lifting 100 tons, constructed for Japanese Navy by Vaughan Crane Co., Manchester, England.

CYLINDERS

Automobile Engines. Ford Engine-Cylinder Production, P. E. Haglund and I. B. Scofield. Soc. Automotive Engrs.—Jl., vol. 11, no. 6, Dec. 1922, pp. 463–471, 21 figs. Principles governing intensive quantity production; sources and methods of handling basic materials that compose Ford engine cylinder; fundamental plan of River Rouge plant.

DIE CASTING

Developments. Developments in Die-Casting Practice, Charles Pack. Machy. (N. Y.), vol. 29, no. 4, Dec. 1922, pp. 281–283, 3 figs. Die-casting dies; location of parting line; draft required in dies for castings made from different alloys.

Equipment. Equipment for Making Die-castings, A. G. Carman. Machy. (N. Y.), vol. 29, no. 4, Dec. 1922, pp. 261–263, 5 figs. Applications of die castings; general principles of die-casting machines; points on design of parts to be die-cast.

EVAPORATORS

Flash. The Flash Evaporator. Power, vol. 56, no. 22, Nov. 28, 1922, pp. 834–835, 3 figs. New type of apparatus for producing distilled makeup water.

Triple-Effect. How a Lillie Evaporator Operates. Power, vol. 56, no. 21, Nov. 21, 1922, pp. 802–804, 3 figs. Operation of triple-effect evaporator that operates on exhaust steam.

FOREMEN

Duties. The Rightful Place of the Shop Foreman, A. H. Rodrick. Indus. Management (N. Y.), vol. 64, no. 6, Dec. 1922, pp. 350–351 and 354. Tells how shop foreman can become most valuable link in management chain.

Training. Training Steelworks Foremen, B. M. Nussbaum. Iron Trade Rev., vol. 57, nos. 21 and 22, Nov. 23 and 30, 1922, pp. 1407–1408 and 1491–1492. Points out that management should participate in training; instruction and fundamentals of industrial management given in iron and steel industry with successful results; club idea failed.

FREIGHT HANDLING

"Veri-Direct" Method. The "Veri-Direct" Method of Handling L.C.L. Freight. Ry. Age, vol. 73, no. 23, Dec. 2, 1922, pp 1053–1057, 6 figs. Method of loading freight from freight houses into cars in use in Ohio region of Erie R. R., which has reduced errors and losses due to wrong loading about 70 per cent as compared with former conditions.

FURNACES, ANNEALING

Continuous. Continuous Annealing Furnaces for Sheets. Iron Age, vol. 110, no. 21, Nov. 23, 1922, pp. 1342–1343, 3 figs. Car-type furnaces with daily capacity of 125 tons each at Ashtabula steel plant; pulverized coal used as fuel. See also article by E. L. Shaner in Iron Trade Rev., vol. 71, no. 21, Nov. 23, 1922, pp. 1423–1427, 8 figs.

GAS PRODUCERS

Mechanically Agitated. The Stein-Chapman Gas Producer with Mechanical Agitator. Engineering, vol. 114, no. 2967, Nov. 10, 1922, pp. 597–598, 8 figs. Embodies Chapman floating agitator and new form of automatic ash extractor.

GEARS

Involute Curve. The Law of the Involute Curve, O. G. Simmons. Am. Mach., vol. 57, nos. 21 and 22, Nov. 23 and 30, 1922, pp. 801–803 and 837–839, 6 figs. Determining lead of involute curve; how right- and left-hand involutes may be generated; finding length of involutes; developed principles applied to generating gear teeth; adapting milling machine to cutting gear teeth with true involute.

HOBBING MACHINES

Testing. Testing Gear-hobbing Machines, D. Vaughn Waters. Machy. (N. Y.), vol. 29, no. 4, Dec. 1922, pp. 304–306, 5 figs. Testing fixtures used by Gould & Eberhardt, Newark, N. J.

HOBS

Manufacturing. Simmons Method of Hob Making, Charles O. Herb. Machy. (N. Y.), vol. 29, no. 4, Dec. 1922, pp. 255–260, 11 figs. Method of simultaneously generating and relieving teeth of gear hobs with revolving cutter resembling spur gear.

INDUSTRIAL MANAGEMENT

Instructions, Illustrated. Illustrated Instructions, Joseph Spielvogel. Management Eng., vol. 3, no. 6, Dec. 1922, pp. 365–369, 5 figs. Shows how, by use of illustrations in connection with such items as assembly drawings, bills of materials, stock, estimating, inventory and cost records, etc., it is possible to apply quantity production principles to manufacture of complicated machinery during plastic stage of development.

Tool Purchasing and Storage. Ordering and Storing Small Tools, W. J. Sansom. Am. Mach., vol. 57, no. 23, Dec. 7, 1922, pp. 869–872, 4 figs. Things to do and to avoid in ordering small tools; inspection and storage methods; systems of getting tools to workmen.

LATHES

Semi-Automatic Multi-Cut. New Semi-Automatic Multi-Cut Lathe, William O. Strauss. Machy. (N. Y.), vol. 29, no. 4, Dec. 1922, pp. 276–278, 4 figs. Machine developed by R. K. LeBlond Machine Tool Co., Cincinnati, turns work up to 12 in. in diam. and is made in various bed lengths giving max. center distances of 18, 26, 34, or 42 in.

LOCOMOTIVES

Power Reverse Gear. All-Service Locomotive Power Reverse Gear. Ry. Age, vol. 73, no. 23, Dec. 2, 1922, pp. 1051–1052, 4 figs. New non-creeping power reverse gear equally adapted to passenger, freight or switching service. Designed by Transportation Devices Corp.

MACHINE TOOLS

Selection. Selection of Machine-Tools, A. J. Baker. Soc. Automotive Engrs.—Jl., vol. 11, no. 6, Dec. 1922, pp. 520–528. Investigates problem of determining when to make change of equipment by substituting new machine tools for old, or special machines for standard.

Standard. Standard Machines Increase Production, L. S. Love. Iron Age, vol. 110, no. 21, Nov. 23, 1922, pp. 1335–1338, 9 figs. Savings effected in use of fixtures rather than in special machines; case of quintupled production. Changes made in production-plant layout at Gray & Davis Division of Am. Bosch Magneto Co.

Standard vs. Special. Standard versus Special Machine-Tools for Automotive Production, R. K. Mitchell. Soc. Automotive Engrs.—Jl., vol. 11, no. 6, Dec. 1922, pp. 472–473. Points out disadvantages attending use of special machines and benefits of using standard equipment whenever possible; possibilities of special jig-and-fixture design that would meet needs of manufacturers of standard parts.

METALS

Behavior under Stress. A Mechanical Model Illustrating the Behavior of Metals under Static and Alternating Loads, C. F. Jenkin. Engineering, vol. 114, no. 2968, Nov. 17, 1922, p. 603, 3 figs. Model is said to be capable of illustrating most of phenomena which metals exhibit when tested in any way under mechanical stresses not exceeding their yield points.

NICKEL-CHROME STEEL

Segregation. Ingot Corner Segregation in a Nickel Chrome Steel, T. Henry Turner. Engineering, vol. 114, no. 2969, Nov. 24, 1922, pp. 662–664, 9 figs. Experiences encountered in examination of large and medium-sized steel forgings which had been received for machining at some of most important engineering works in England. Paper read before Staffordshire Iron & Steel Inst.

POWER PLANTS

Economy in. The Cost of Power Per $100 of Pay-Roll, P. F. Walker. Management Eng., vol. 3, no. 6, Dec. 1922, pp. 339–342. Discusses economizing in power by (1) saving in fuel through greater efficiency at source, and (2) saving by eliminating losses in transmission and application within establishment.

PULVERIZED COAL

Equipment. Rochester Plant Installs Pulverized Fuel Burning Equipment, R. D. DeWolf. Power, vol. 56, no. 22, Nov. 28, 1922, pp. 845–847, 2 figs. Furnaces of two 8750-sq. ft. boilers converted to burn pulverized fuel; pulverizing equipment and coal bins located directly above boilers; no conveyors or driers used; one operator handles both boiler and pulverizer.

Power Plants. Modern Industrial Plant Burns Pulverized Coal. Power, vol. 56, no. 23, Dec. 5, 1922, pp. 868–874, 8 figs. New plant of Eline's, Inc., Milwaukee, contains complete fuel-preparation plant; special ventilation of furnace walls; economizers and hot-process water-softening system.

RAILWAY MOTOR CARS

Requirements and Future of. Motor Cars on Rails. Soc. Automotive Engrs.—Jl., vol. 11, no. 6, Dec. 1922, pp. 481–490, 5 figs. Contains following papers: The Field for the Rail Motor-Car, Roy V. Wright; Some Requirements for the Rail Motor-Car, W. L. Bean; Automotive Rail-Cars and Their Future Development, L. G. Plant.

REFRIGERATING PLANTS

Equipment Specifications. Value of Specifications in Purchasing Refrigerating Equipment, A. C. Bishop. Power, vol. 56, no. 23, Dec. 5, 1922, pp. 884–886. Paper read before Nat. Assn. Practical Refrig. Engrs.

STEAM ENGINES

Standard Extraction. Tandem Extraction Engine for Combined Power Production and Exhaust Steam Heating. Engineering, vol. 114, no. 2967, Nov. 10, 1922, pp. 584–585, 5 figs. partly on p. 558. Tandem compound engine, in which steam required for heating purposes is drawn from receiver between two cylinders.

Uniflow. Unaflow Valve Gear of American Design. Power, vol. 56, no. 23, Dec. 5, 1922, pp. 880–881, 6 figs. Describes several valve gears used on Filer & Stowell uniflow engines. Method of setting valves.

STEEL

Carbon, Manganese Effect on. Effect of Manganese on Carbon Steels, Henry S. Rawdon and Frederick Sillers, Jr. Iron Age, vol. 110, no. 21, Nov. 23, 1922, pp. 1357–1361, 7 figs. Their structure as affected by varying percentages; manganese as strengthening factor in low and medium steels. Published by permission of Bur. of Standards.

STEEL, HEAT TREATMENT OF

Case-Hardened Articles. Heat Treatment of the Core of Case Hardened Articles, H. B. Knowlton. Forging & Heat Treating, vol. 8, no. 11, Nov. 1922, pp. 526–528, 5 figs. Study of effect of carburizing heat upon core and of structure and strength of article carburized after various heat treatments.

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Mechanical Engineering

The Monthly Journal Published by

The American Society of Mechanical Engineers

Publication Office, 207 Church Street, Easton, Pa. Editorial and Advertising Department at the Headquarters of the Society, 29 West Thirty-ninth Street, New York

Volume 45 February 1923 Number 2

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DEPARTMENTAL

ADVERTISING

Price 50 Cents a Copy, $4.00 a year: to Members and Affiliates, 40 cents a Copy, $3.00 a Year. Postage to Canada, 75 Cents Additional; to Foreign Countries, $1.50 Additional. Changes of address should be sent to the Society Headquarters.

Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879.
Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921.

Contributors and Contributions

Methods of Ash Handling

John Hunter

Methods of removing ashes from boiler rooms, and systems of conveyance are described and illustrated in an article by John Hunter and Alfred Cotton, chief engineer and chief of the research department, respectively, of the Heine Boiler Company of St. Louis. Mr. Hunter was born in Scotland. He became a seagoing engineer at the age of twenty and during the Spanish-American War was chief engineer of the *St. Paul*, operated by the U. S. Navy. In 1905 Mr. Hunter became chief engineer for the Union Electric Light and Power Co., of St. Louis, and later aided in the development of the hydroelectric station which supplies this company with 60,000 hp. over a 100,000-volt transmission line.

Alfred Cotton

Mr. Cotton received his technical education through university-extension courses and private tuition in England while serving an apprenticeship in marine engineering. In 1903 he came to America where he developed the Cotton furnace. He manufactured and installed these furnaces until the war, when he entered the employ of Colt's Patent Fire Arms Manufacturing Co.

Stresses in Electric-Railway Motor Pinions

The results of a scientific study undertaken by the General Electric Company for the development of superior electric-railway motor pinions are reported in this issue by Dr. Paul Heymans and A. L. Kimball, Jr. Dr. Heymans, who is research associate in industrial physics at M.I.T., was born in Belgium in 1895 and educated at the University of Ghent, L'Ecole Spéciale des Travaux Publics in Paris, and the University of London.

A. L. Kimball, Jr., has been research physicist at the research laboratory of the General Electric Company since 1918. He was graduated from Amherst College in 1908 and from the Harvard Engineering School in 1914. He spent the year 1919–1920 in London studying Dr. Coker's method of stress analysis by the use of transparent models.

Torsion of Crankshafts

Dr. S. Timoshenko, who has recently become consulting engineer for the Vibration Specialty Co. of Philadelphia, presents a paper which discusses how the torsional properties of a crankshaft with a single throw may be determined. Dr. Timoshenko came to the Vibration Specialty Co. from St. Petersburg, where he occupied at the Polytechnic Institute the chair in the Theory of Elasticity as Applied to Ships.

Design of Cooling Towers

Prof. C. S. Robinson of the Massachusetts Institute of Technology has established a general principle applicable to cooling-tower design and derived equations for the use of the designer. In his paper in this issue he shows by actual experiment how these formulas are applicable. Professor Robinson was formerly a chemist in the employ of the Sherwin-Williams Co., the Rosseler and Hasslacher Co., and the Walworth Manufacturing Co.

Size Selection of Dry-Vacuum Pumps

A rapid and practically accurate method for determining the size of dry-vacuum pump to employ under any set of conditions is described by Edward W. Noyes and Harold V. Sturtevant, sales engineers for the Sullivan Machinery Company of Claremont, N. H., and Chicago, Ill. Both Mr. Noyes and Mr. Sturtevant are graduates of the Massachusetts Institute of Technology, class of 1921.

Feed Heating for High Thermal Efficiency

Linn Helander, a Junior Member of the Society, presents the results of an investigation made for the purpose of determining the correct feed-water temperatures for conditions of high thermal efficiency. Mr. Helander, after his graduation from the University of Illinois in 1915, was steam and hydraulic engineer for the Pittsburgh Crucible Steel Co. During the war he was supervising engineer of tests for the Ordnance Department in the Montreal district. Since 1919 he has been with the Westinghouse Electric and Manufacturing Co.

Lumber Dry Kilns

Thomas D. Perry, vice-president and manager of the Grand Rapids Veneer Works, believes that scientific kiln drying offers engineers a splendid field for research work. His paper pays particular attention to the several classes of ventilated kilns. Mr. Perry received his A.B. degree from Doane College in 1897 and his B S. in Mechanical Engineering from M.I.T. in 1900.

German Submarine Diesel-Engine Clutch

During the five years spent as supervising draftsman for the U. S. Navy Department, W. H. Nicholson had an opportunity to study the German types of submarine equipment. His paper gives to American builders of Diesel engines facts about German Diesel-engine clutches. Mr. Nicholson has done engineering drafting and designing for the New York Shipbuilding Corporation, the National Aniline Co., and the Newton Machine Tool Works. At present he is with the Westinghouse Electric and Manufacturing Co.

Coming A.S.M.E. Events

Pacific Coast Regional Meeting
Los Angeles, April 16-18, 1923

Spring Meeting
Montreal, May 28-31, 1923

Southern Regional Meeting
Chattanooga, October, 1923

MECHANICAL ENGINEERING

Volume 45 February, 1923 No. 2

Methods of Ash Handling

By JOHN HUNTER[1] and ALFRED COTTON,[2] ST. LOUIS, MO.

Various methods of handling ash are described and illustrated in this paper, the greater part of which deals with stationary practice, beginning with rudimentary and progressing to the most modern installations, of which schematic and actual examples are given

Methods of removing ashes from basement boiler rooms are followed by a discussion of the design, construction, and capacity of hopper ashpits, including their doors and water seals. Systems of mechanical conveyance and elevation are described, comprising ash cars, skip hoists and bucket conveyors. Fluid conveyance, as represented by water sluicing and steam-jet conveyors, is discussed in general, and typical examples of both are illustrated and described in detail. Particulars of ash bunkers and settling basins are also given.

ASH HANDLING is just as important as coal handling. It was originally accomplished entirely by hand, but with the growth of the size of boiler plants it is now either partly or entirely mechanical. There are three general methods of conveyance in use; air, water, and purely mechanical.

The great development of the central electric generating station has compelled operating engineers to give much attention and thought to ash handling. It is only a few years since boilers of 600 hp. were considered large, while today 2000-hp. units are not at all uncommon and some 3000-hp. boilers are in use. Furthermore, while boilers were usually operated at about their rating of 10 sq. ft. of heating surface to the boiler horsepower, they are now commonly operated at twice their nominal rating; and in the larger central stations it is common practice to run them for short intervals at three or even

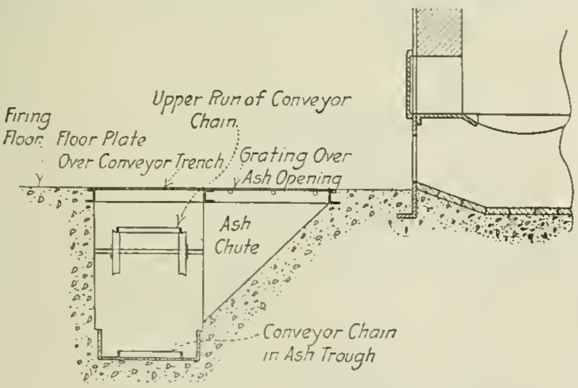

Fig. 1 Chain and Cross-Bar Conveyor

four times their rating. The bearing of this development on ash handling may be strikingly seen when we remember that a 250-hp. boiler running at rating and burning coal with 15 per cent of ash would make 150 lb. of ash per hour; while each 2000-hp. unit at 200 per cent of rating makes well over a ton of ash per hour.

While the complete paper deals with both stationary and marine practice, the present abstract is limited to the former, although definite progress in ash handling was first made on shipboard.

Except that there are several standardized types of conveyors, classification of methods of ash handling is not convenient and would serve no useful purpose. Therefore no real classification will be attempted, but several different schemes and installations will be described.

The most rudimentary method is that in which the ashes are hoed out of the fire doors and ashpits on the firing floor and shoveled into wheelbarrows. In some cases the ashes are shoveled into industrial railway cars, which are then pushed to the dumping point. The wheelbarrow can be replaced by either a mechanical or air conveyor.

Fig. 1 is a cross-section of a block-chain conveyor running in a trench under the firing floor. The ashes are hoed on to the grating through which they fall down the chute to the bottom of the trench. They are then drawn along by the chain, discharging into a bucket elevator as illustrated in Fig. 2, or on to an inclined chain conveyor carrying the ash into an elevated storage hopper.

Where there is a plentiful supply of water, a flume may be car-

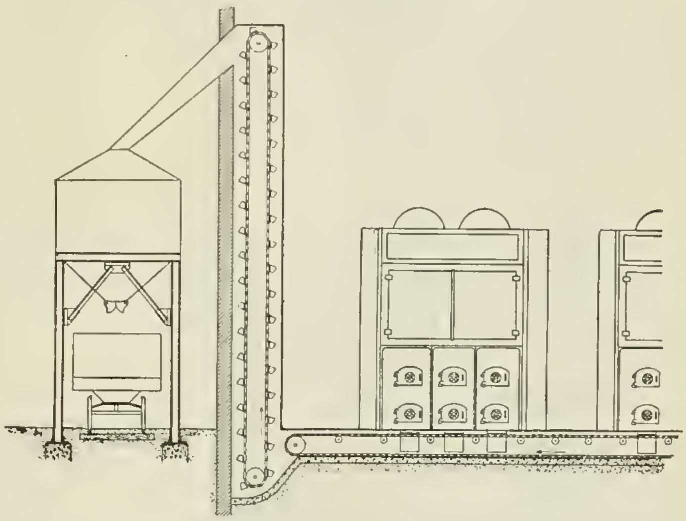

Fig. 2 Chain and Cross-Bar Conveyor with Bucket Elevator and Ash Bunker

ried along under the firing floor and the ashes raked into it through openings.

The problem is more complicated when the boiler room is considerably below the ground level, as in office buildings, hotels, etc. Whatever the final disposition may be, the ashes are invariably removed from the vicinity in motor or horse-drawn trucks. Here, the important consideration is principally that of hoisting the ashes from the boiler room to the street. In the isolated heating plants of the Union Electric Light and Power Company in St. Louis, the ash trucks are equipped with a davit just like a regular boat davit on shipboard. A small winch with a 4-in. barrel geared to a $^1/_4$-hp. electric motor is mounted at the side of the truck. A $^3/_{16}$-in. steel wire rope is attached and wound on the winch barrel, and passed through a pulley block hanging from the head of the davit with a hook at the free end. Current for the motor is conveyed by a flexible cord from a socket in the plant and snapped to the motor when the ash truck arrives. Opening the sidewalk cover, the hook is dropped and the first ash can attached, quickly hoisted to the davit head, the davit swung around and the ash can dumped into the wagon, and then returned to the basement. The whole operation is completed in a few minutes.

In some instances the air conveyor (the so-called steam-jet conveyor) has been used very advantageously in hospitals, hotels,

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Contributed by the Materials Handling Division and presented at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. Abridged. All papers are subject to revision.

and office buildings in crowded parts of cities, but it is not always applicable.

Another method is the "post box" elevator. The ashes are stored in the boiler room until the arrival of the ash truck. The elevator, which is of the bucket type, has a telescopic housing which is pushed up through the sidewalk opening and the chute extended to discharge into the truck.

The first opertion where labor can obviously be saved is in avoiding hoeing and shoveling ashes at the outset. This leads naturally to a consideration of the hopper ashpit.

Hopper Ashpits

The hopper ashpit is regular practice in the modern plant. Its

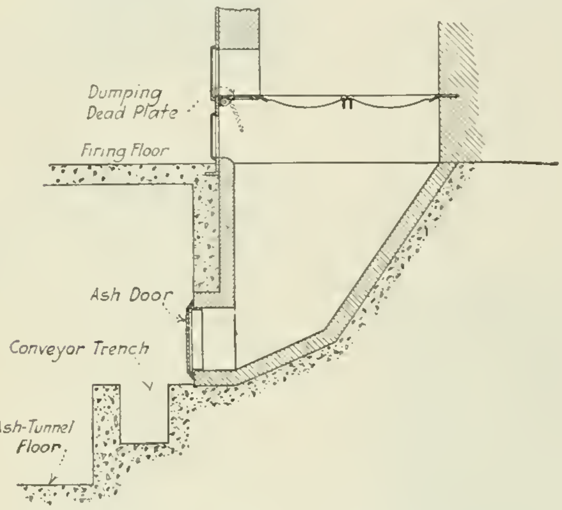

Fig. 3 Hopper Ashpit for Hand-Fired Furnace

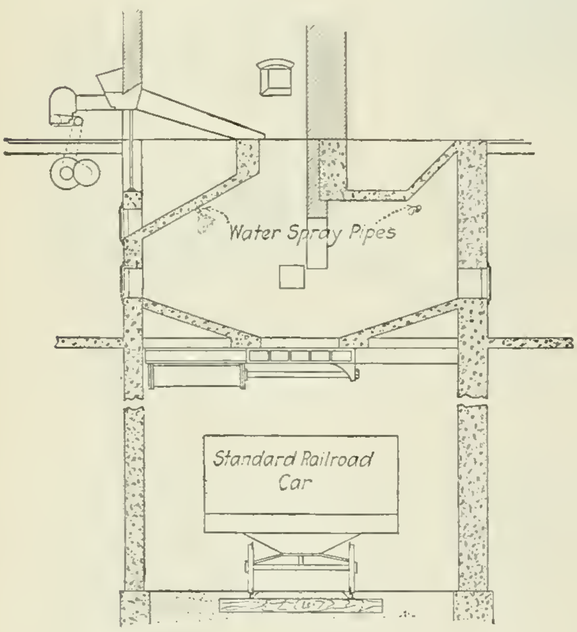

Fig. 4 Large-Capacity Hopper Ashpit

size and general design will depend primarily upon the manner in which the ashes flow into it, the method of removal, and also upon the system of draft. The design begins at the top to suit the stoker.

In hand-fired, forced-draft anthracite plants the top of the hopper will conform to the whole grate area. With stationary grates fine ash is falling constantly over the whole area. As the fires are hand-cleaned, a dumping deadplate will keep the ash away from the firing floor and allow it to fall directly into the hopper, the forced draft being temporarily shut off. With dumping grates the ash will also fall from most of the grate surface. The discharge door must be airtight to avoid increasing the cost of generating the forced draft and the possible reduction of ashpit pressure's lowering the boiler capacity. If it can be dumped directly into railroad cars the basement being deep enough for this purpose, the hopper can be quickly dumped through bottom doors. Where conveyors are installed it is usual to use a side door and work the ashes out gradually into the conveyor to avoid choking it, as would happen with a straight dump. Fig. 3 illustrates a layout of this kind. The conveyor will occupy the trench in front of the ash door. It may be mechanical, bucket or chain, or air or water, and is therefore shown schematically only.

With forward-travel underfeed stokers, chain-grate stokers, front-feed inclined stokers, and others the ashes are dumped at the rear of the furnace and the top of the hopper will be the width of the fire but of small dimension from front to rear to accord with the stoker dump. This reduces the capacity for storage as is seen by

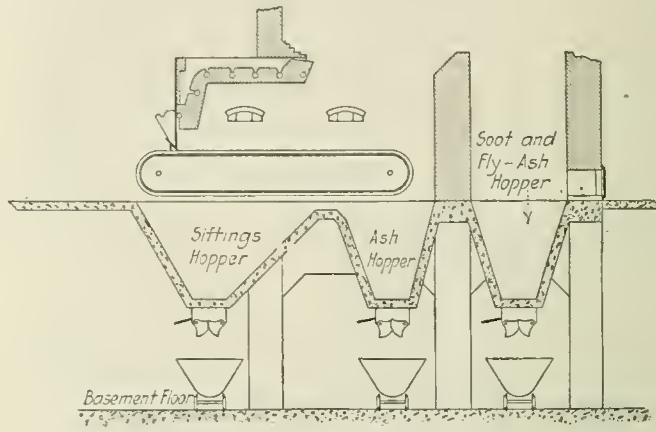

Fig. 5 Hoppers for Ashes, Coal Siftings, and Soot

examining Fig. 5. Where large storage is imperative, the ashpit may be designed as in Fig. 4, which is drawn from an illustration appearing in *Power* of January 17, 1922. Owing to the flatness of the bottom, some hand labor is necessary to effect complete discharge when desired.

With chain-grate stokers a hopper should also be provided for fine coal which shifts through the grates before ignition. Such an

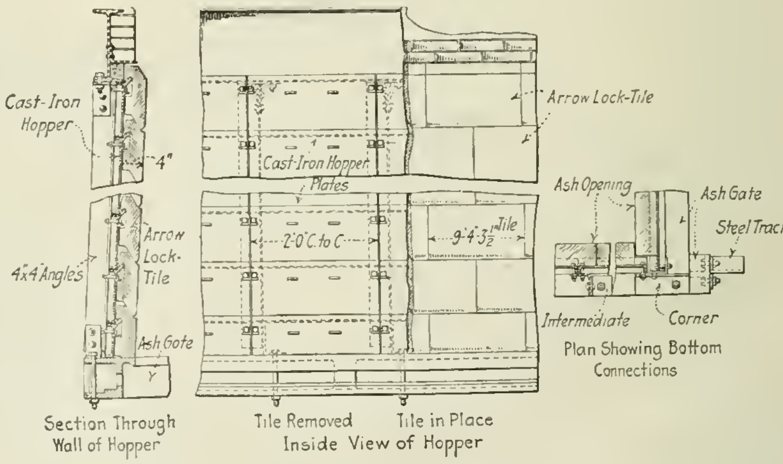

Fig. 6 Baker-Dunbar-Allen Ashpit

arrangement is shown in Fig. 5. This coal is dumped into some means of conveyance to be returned to the stoker coal hoppers.

Side-travel underfeed stokers dump at each side of the wind box for the whole depth of the fire. Hopper ashpits for this type of stoker may therefore have greater storage capacity since the top of the hopper extends to the front of the boiler.

Capacity. In some instances very little capacity may be sufficient, owing to storage being taken care of outside the ashpit. The method of conveyance from the ashpit will have considerable bearing on the ashpit capacity necessary. But 24 hours' capacity should usually be provided in case of breakdown of conveyors, etc.

Since the required capacity depends upon the amount of ash that accumulates between emptyings, it is controlled by the rate of

firing and the percentage of ash in the coal. Multiplying the weight of coal burned between dumpings by the percentage of ash and allowing 40 lb. per cu. ft. gives the storage space required. Allowance must be made for unburned coal coming in with the ash, for neglect to empty regularly, for possible increase in the load and consequently in the rate of combustion, and for possible change to dirtier coal. The careful engineer will make the capacity of his ashpits perhaps 50 per cent greater than the calculations show, or even more.

Design. The sides should slope at not less than 45 deg. in any case, and a minimum of 50 deg. with the horizontal is preferable. If one side is vertical the opposite side may have the minimum slope; but where two opposite sides slope, neither should slope less than about 55 deg. If the slope is too small, arching of the ash is likely to occur. Where the width of the hopper would necessitate too great height to get these required slopes, the ashpit may easily be divided so as to have a number of discharge openings. An excellent example of reversed slope which results in absolutely reliable dumping is illustrated in Fig. 13.

If a very small slope is used so as to get large capacity such as in Fig. 4, access doors should be provided at the top of the slope so that the ashes may be pushed to the dump doors with a minimum of labor, and ample space should be left so that long ash tools can be wielded with ease.

Large discharge openings should be used, though their size depends to some extent upon the method of firing. Modern practice requires 30 to 36 in. as a minimum, with many instances of clear openings 5 ft. square.

The bottom discharge is undoubtedly the least costly in labor and well repays the added expense of the greater height of basement needed. The height of the bottom of the hopper above the basement floor depends upon the system of conveyance adopted. It is greatest where standard railroad cars are used, about 8 or 9 ft. to clear the cars and about 17 to 18 ft. if a locomotive must pass under. With industrial cars 5 or 6 ft. is sufficient, though a clear headroom of 6 ft. 6 in. to 7 ft. is preferable. In any case there should always be sufficient vertical space to allow a bar to be pushed up into the hopper to clear away any obstruction. In designing new plants ample headroom should always be provided.

Where storage takes place in the ashpit, water spray pipes should be provided for quenching the ashes. These pipes should be near the top and sheltered from the incoming ash. Or a substantial spray ring such as illustrated in Fig. 9 may be used. Many prefer to make the hopper sufficiently large for the ashes to remain long enough to cool naturally. If too much water is used it will leak from the dump doors and flow about the basement; and as it contains much fine ash in suspension, it will clog sewers and necessitate cleaning them frequently.

Construction. Hopper shells made of sheet steel lined with firebrick are undesirable owing to rapid corrosion from sulphur in the ashes. Shells of reinforced concrete about 6 in. thick are common and satisfactory. The most modern construction, and probably the best method so far devised, is to use a structural-steel skeleton and make the shell of substantial cast-iron flanged plates bolted together.

Owing to the heat of the ashes and the possibility of the combustion of unburned coal, the hopper shells should always be lined with firebrick, which may be of second quality. With proper quenching of the hot ashes with water sprays a lining of well-burned hard paving brick is very satisfactory.

The method of construction of the Baker-Dunbar-Allen hopper ashpit is illustrated in Fig. 6. A suspended skeleton of structural steel carriers the hopper shell of heavy cast-iron flanged plates. The lining is of special firebrick blocks which will not spall under the temperature changes which occur. As seen in the left-hand view these blocks are hung from the shell and interlocked in a manner that prevents displacement but allows of easy renewal, and no mortar joints are used.

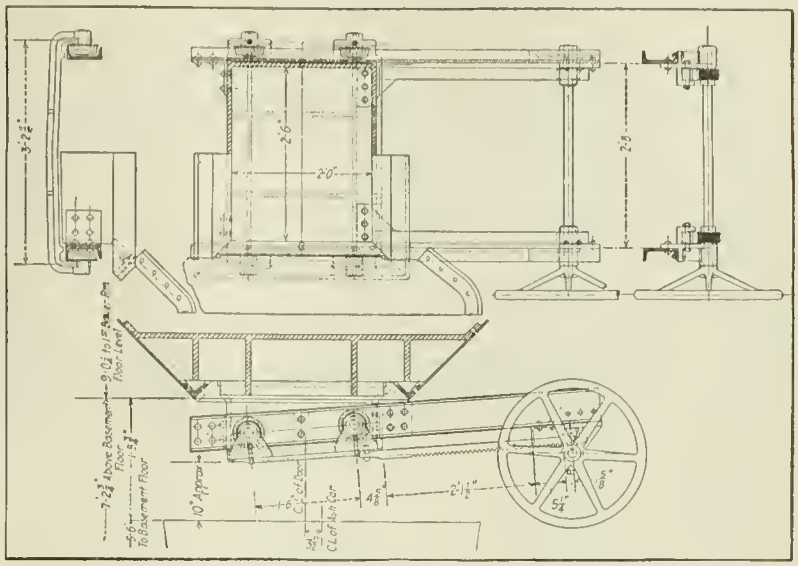

Fig. 7 Assembly of Ashpit Door and Frame

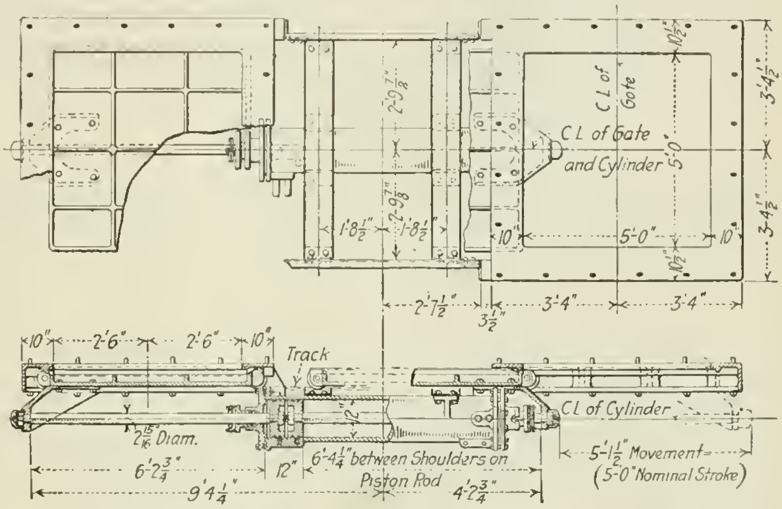

Fig. 8 Baker-Dunbar-Allen Power-Operated Ash Doors

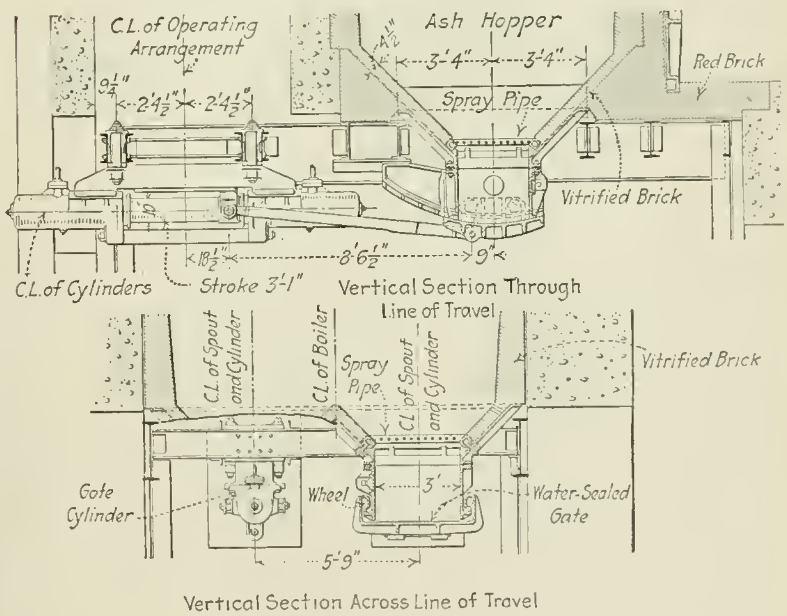

Fig. 9 Diescher Power-Operated Ash Doors

Closures. Hopper ashpits will usually be provided with doors to retain the ash and prevent the passage of air, and to allow of the ash being dumped or hoed out at intervals as desired.

Airtight ash doors are highly desirable in almost all cases. There are several ways in which the dump openings may be sealed. The

doors and faces may be machined, or the frame may be provided with a groove packed with asbestos rope, while the door has a rib or tongue which is squeezed into the asbestos packing by a crossbar and screw spanning the door. The latter method has been used with satisfaction in vertical doors like that of Fig. 3. The doors should usually be lined with firebrick to prevent warping due to hot ashes lying on them soon after dumping.

An example of ash door is illustrated in Fig. 7. These doors are of substantial construction, and are carried on rollers running on steel members. They are operated by hand with rack and pinion. Smaller doors are operated by hand, but when the openings approach 3 ft., power operation is advisable for speed. The larger hand-operated doors are worked by gearing, such as rack and pinion, while power operation may be hydraulic, compressed air, or electric.

Fig. 8 illustrates two Baker-Dunbar-Allen dumping doors arranged for compressed-air or hydraulic operation. The cylinder is worked between the openings and contains two pistons, one connected to each door. The doors are lined with firebrick.

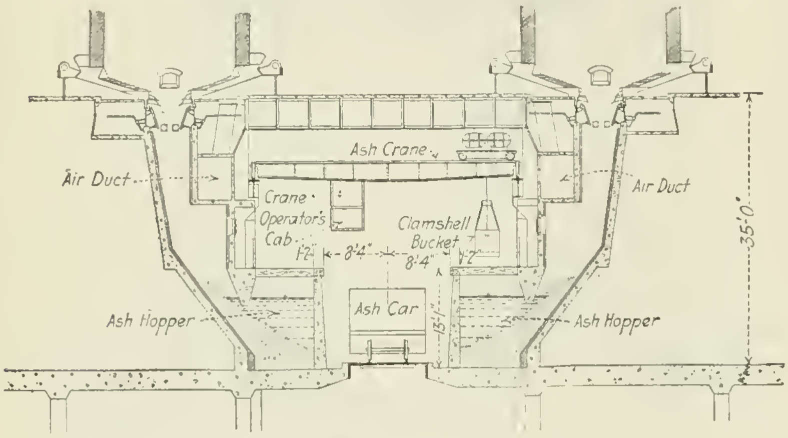

Fig. 10 Water-Sealed Ashpit

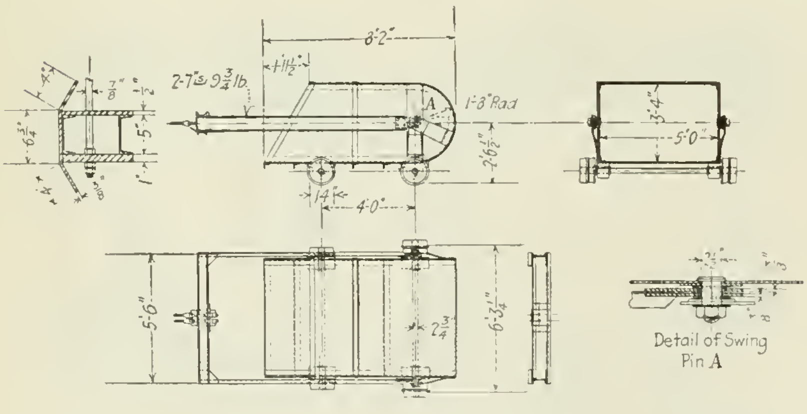

Fig. 12 Details of Skip-Hoist Bucket

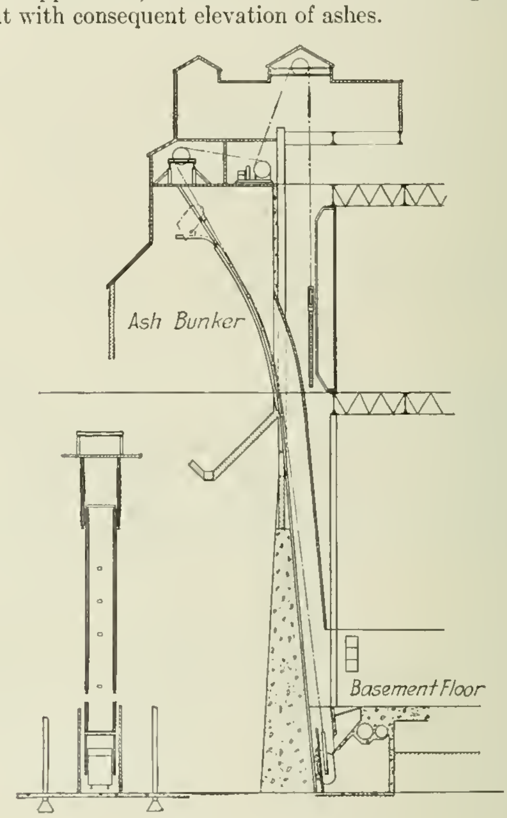

Fig. 11 Skip Hoist

The Diescher dumping door shown in Fig. 9 is provided with rollers which run on a curved track. Owing to the curvature of the door in conjunction with the flanges which carry the rollers, it retains water to form a seal and this water renders lining unnecessary. The door can be run off the track and another door run on if replacement is ever necessary by simply removing the pin of the driving connection. There is ample power and strength to shear easily through any clinkers which may get caught during closing.

Instead of using doors, closure may be effected by water seal. This method may be described as a U-tube with one leg forming the hopper ashpit while the other is open to the atmosphere and possibly to the entrance of a clamshell bucket. Water in the bend of the U-tube forms a seal and serves to quench the ashes.

An excellent example of this method is illustrated in Fig. 10, which is a cross-section of the boiler room of the Springdale Station of the West Penn Power Company. More than sufficient water for the seal is provided by the waste cooling water from the clinker grinders. The overflow is from one ashpit to the next, until it is finally discharged from the last ashpit. This system of ashpit requires considerable depth of basement—not less than about 30 ft. from firing floor to basement floor.

A further advantage of this method is that no combustible or corrosive gas escapes into the basement. When boilers are being pushed with heavy loads, gas often escapes from hopper dump doors. Apart from discomfort and danger to those in the basement, considerable corrosion of ironwork often occurs. Such troubles are entirely obviated with the water-seal ashpit.

Mechanical Conveyance

The method of conveying ash by emptying ashpits into small dumping cars has a great deal to recommend it. The cars are inexpensive, can be moved by men, animals, tractors, or locomotives, and can be run about the floor or on tracks, all according to the amount of ash to be moved and other conditions.

In the Ashley Street Station of the Union Electric Light and Power Company, St. Louis, Mo., a system of industrial railway and ash cars was installed in 1905. The basement floor of this plant is 30 ft. below the flood stage of the Mississippi River, and this necessitated a watertight basement with consequent elevation of ashes.

The boilers are equipped with chain-grate stokers discharging ash into hoppers having a capacity of 24 hours. These hoppers are of steel plate lined with vitrified brick laid in cement, and each has two large horizontal dumping doors which are illustrated in Fig. 7.

The railway is 30 in. gage and the dumping cars have a capacity of three tons each. The cars are lifted 120 ft. to an elevated ash bunker by a skip hoist installed in 1916 to replace the car elevators originally employed; a gasoline locomotive is used to haul the ash cars. The general arrangement is illustrated in Fig. 11. The details of the bucket are presented in Fig. 12.

The operation of the skip hoist is mainly automatic. When an ash car has been dumped into the bucket, a switch button is pressed. This starts the hoisting motor, which raises the bucket to the top of its travel where it turns over and discharges into the elevated bunker. A switch trip at this point reverses the motor and thus lowers the bucket to its starting point, where another switch trip stops the motor.

The operation of this new system is entirely satisfactory and it has given good service. It has reduced the labor cost of handling ash one-third and the cost of maintenance one-half.

In the system installed at the New Bedford Gas and Electric

Light Company's plant, the ashes collected in hopper ashpits are emptied into a storage-battery truck having a dump body of 40 cu. ft. capacity. An automatically controlled skip hoist with the skip car normally in a small concrete pit just large enough to hold the car, is installed about 39 ft. outside the boiler room. The truckman pushes a button switch which starts the elevator motor, and this raises the car, dumps it into the ash bunker, and returns it to the concrete pit ready for another load. Two men handle the ashes from the station, which has a load of about 38,000 kw. at the present time.

Fig. 13 illustrates a hopper ashpit arranged for dumping directly into standard gondola railroad cars which form part of the equipment of the station. The hoppers are lined with brick, not shown, and have a capacity of about 2500 lb. of ashes. The stokers are equipped with clinker grinders. The ash gates are of the sliding type and are operated by compressed-air cylinders. Water spray pipes are provided near the top of the hoppers for wetting down the ashes before dumping.

The present consumption of this station is 413,000 tons of coal per year. The yearly ashes from the station amount to 52,800 tons.

The ash cars are handled by an electric locomotive and are dumped into an outside pit, from which they are recovered by a crane and grab bucket and loaded into the purchaser's trucks. The proceeds very nearly pay the labor cost of handling the ashes.

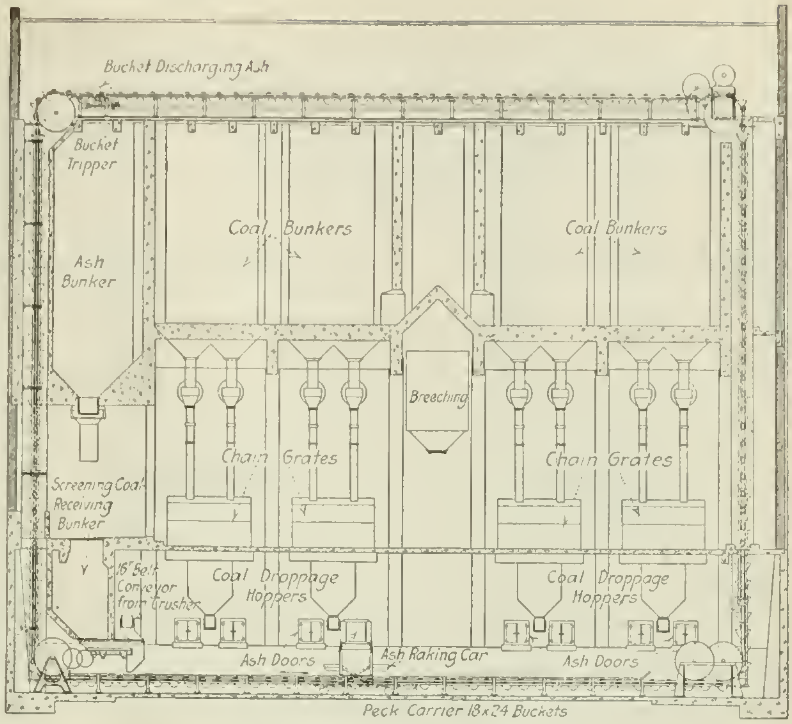

Fig. 14 Peck Carrier Ring System

It is estimated that 45 lb. weight of compressed air is required per day per boiler to operate the hopper-ashpit dumping doors. From recent tests it is found that 1030 gal. of water is used in spraying one ton of ashes, and this amounts to about 4 per cent of the total general-service water used by the station.

Bucket conveyors such as the Peck carrier have been extensively used. With the chain and buckets forming a ring system, the conveyor is often used for coal in the daytime and ash at night.

Fig. 14 illustrates a Pack carrier installation by the Link-Belt Company in a downtown heating station where coal and ash have be handled by motor truck. The building occupies the entire site, and no projections of any kind are possible. The basement floor is 12 ft. below the alley level, and as the alley is only 15 ft. wide it was necessary to build a recess where the trucks could drive in and dump coal, and then load up with ashes.

The conveyor is located centrally between the boilers and handles coal as well as ashes, and also the siftings from the chain-grate stokers. The run-of-mine coal is screened as it is dumped from the truck, the screenings going directly through the feeder to the conveyor, and the lumps passing through the crusher. The vertical lift is 66 ft. and the horizontal centers are 85 ft. The overlapping buckets are 18 in. wide and 24 in. on centers. A 7.5-hp. motor drives the conveyor at a speed of 45 ft. per min. The buckets are discharged into the overhead bunkers by a regular tripper on the upper run.

The coal bunker is continuous along the boilers. The ash bunker which has a capacity of 130 tons, is located in line with and immediately adjacent to the coal bunker and at the same elevation. Consequently the buckets discharge coal into the coal bunker or ash into the ash bunker according to the position in which the tripper is placed. Also, the ash-bunker discharge is immediately above the recess into which the trucks are driven, just as the coal-receiving hopper is immediately below it. Therefore the trucks, which have automatic dump bodies, drive into the recess over the coal-receiving hopper, discharge their load, and receive ashes without changing their position. Quick unloading and reloading therefore materially increases the road time of the trucks; and this is a considerable item in the downtown district where traffic is more or less restricted.

A novel method is employed for the removal of the ashes from the ash hoppers to the conveyors. A double raking apron is contrived as a car mounted on tracks and straddling the conveyor. It is movable the entire length of the boiler house and can be brought in front of each ash door, forming a continuous chute from the hopper door to the conveyor. The operator stands on one side of the car and pulls the ashes down into the chute. After a flow of ashes has been created, water under pressure is used to keep up the flow, and the ashes are removed in a very short time. The cross-section of the plant shown in Fig. 15 illustrates this clearly.

Owing to the abrasive nature of ash the maintenance cost of mechanical conveyors is high. The ashes grind away the connecting pins, and even with regular renewals the pins sometimes wear excessively and cause breakdowns.

The life of these conveyors is considered to be about seven or eight years, and extensive repairs must be made every two or three years. The excessive cost of maintenance has led to their replacement in some installations with electrically operated cars carrying the ashes to outside pits from which they are loaded into railroad cars with a bridge crane, and the cost of handling has been reduced by 50 per cent.

Hopper ashpits with large doors should not be dumped directly on to chain or bucket conveyors. With direct

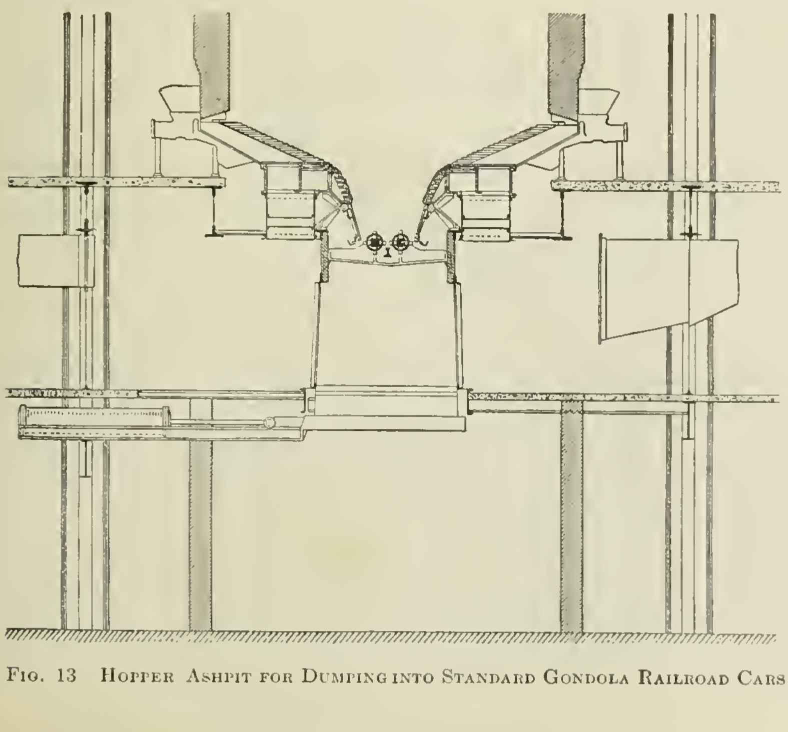

Fig. 13 Hopper Ashpit for Dumping into Standard Gondola Railroad Cars

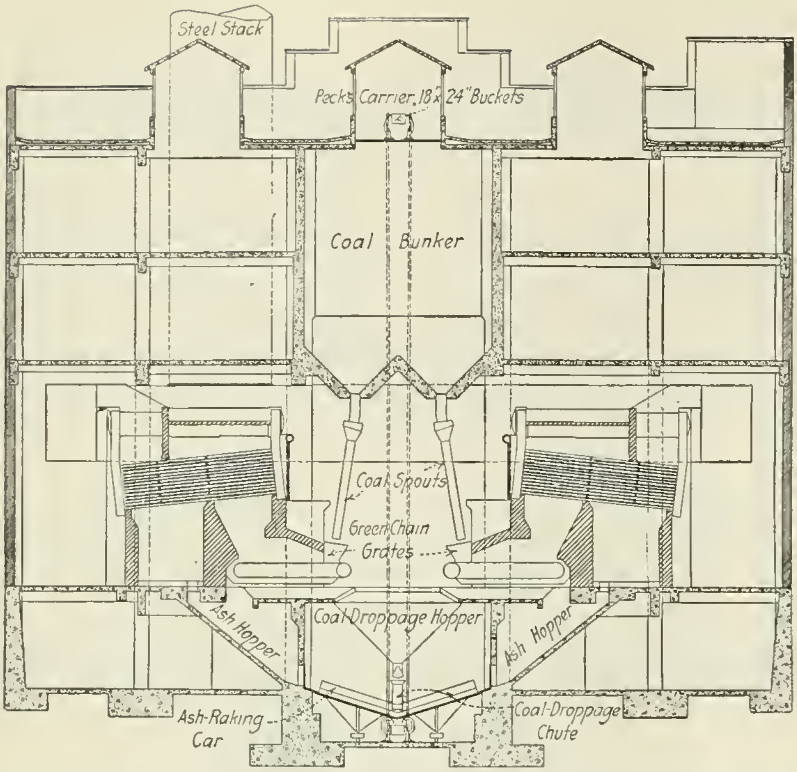

Fig. 15 Cross-Section of Boiler Room with Peck Carrier

dumping, large clinkers are liable to jam and cause breakdown, and opportunity should be given for breaking them.

The Fisk Street and Quarry Street stations of the Commonwealth Edison Company of Chicago are each equipped with bucket conveyors which handle both coal and ashes. There is an additional pair of ash conveyors at Quarry Street which carry the ashes to the train shed. The electrically operated ash cars now used in place of the apron conveyors formerly employed are dumped into a pit outside the building. A bridge crane takes the ashes from the pit with a grab bucket and loads them into railroad cars. The cost of maintenance as compared with the apron conveyors is almost negligible. The outside pit and crane were originally installed for and used with the apron conveyor.

At Northwest and Calumet stations, Chicago, the ash is dumped from hopper ashpits directly into railroad cars. The only maintenance required is upkeep of ashpit linings and dumping doors. The cost of the ash-handling system at these stations cannot well be estimated because there is none.

An example of a simple chain and cross-bar conveyor is illustrated in Figs. 1 and 2. The conveyor installed at one of the municipal plants of the Poplar Borough Council in England and illustrated in Fig. 16, may be considered as a development of this idea in combination with the water seal of Fig. 10, though there is no ashpit storage. In fact, there is no ashpit, only sheet-steel unlined chutes ending in cast-iron nozzles which dip below the water level in the conveyor trough, thus providing the water seal. The return of the chain is also below the surface of the water. The transverse centers of the chain are $19^1/_2$ in. apart and the cross-bars are $25^1/_2$ in. pitch. Therefore large clinkers easily fall between the upper run of the chains and cross-bars to the bottom of the trough. The end of the trough is carried upward at an angle of 41 deg. to its discharge into the ash bin, from which the ash is recovered by grab bucket.

No ash crushers are necessary as the space between chains and cross-bars is sufficient to allow large clinkers to fall through the upper run of the chain into the water; and the hot clinkers break up on falling into the water, the average size as delivered from the conveyor being about equal to that of a pea.

The length of this conveyor is about 140 ft. and it is designed for a chain speed of 20 ft. per min. One conveyor running at 9.5 ft. per min. and handling 3.25 tons of ashes per hour takes a little under 2 hp.

Air Conveyors

Air is passed through a pipe at a sufficiently high velocity to carry the ashes along with it. The air is admitted at one end and ash intakes are provided wherever required. There are two systems of generating the air current. In one, the pipe outlet is connected to an ash-storage tank in which a vacuum is caused by means of a steam-jet or mechanical exhauster. In the other, the air current is induced by a steam jet between the ash intakes and the outlet.

A typical layout of an air conveyor with vacuum storage tank is illustrated in Fig. 17. A steam-jet exhauster is attached to the top of the tank and may discharge into the atmosphere or into the chimney or a silencer to reduce the noise. It is claimed that ordinary gray-iron piping may be used, and a test is offered wherein a piece of conveyor pipe was replaced with light wrought-iron pipe which showed but little wear after a year's service carrying 5000 tons of ash.

An ash tank is not required as a part of the system. It is usual for the conveyor to discharge into an elevated ash tank supported on columns, so that carts, motor trucks, or railroad cars may be run underneath the tank and be filled quickly by opening the ash valve in the bottom.

The ash particles may momentarily attain velocities approximating to that of the steam jet at a little distance from the muzzle of the nozzle, and therefore local abrasion may be considerable. It is usual to locate the motor jet at an elbow, as it is then convenient to aim the jet in the new direction. When the conveyor pipe is very long, extra nozzles are installed in some cases. When the nozzles are arranged in straight pipe they are set at an angle to the axis of the pipe and are then not so efficient as they would be if coaxial. An air inlet is provided at the beginning of the pipe, for it must be remembered

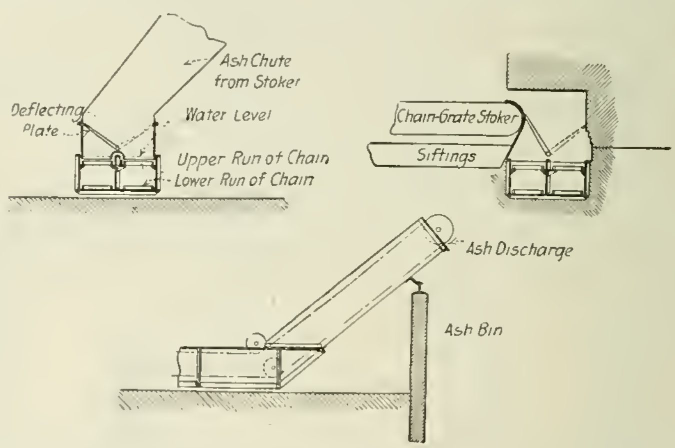

Fig. 16 Water-Seal Chain and Cross-Bar Conveyor at Poplar, England

that it is the velocity of a large body of air which carries the ash, and not the vacuum.

As an instance of the speed at which ashes can be handled, a plant may be cited containing fifteen 500-hp. boilers equipped with Murphy stokers, where the average amount of ashes in each pit ranges from 1000 to 1300 lb. One man cleaned out eight ashpits in 27 min. from the time steam was turned on until it was turned off.

Some stokers are provided with clinker crushers, and when this is not the case it is becoming increasingly necessary to add clinker crushers as part of the ash-handling equipment, so that the clinkers may be reduced to such size as the conveyors can handle without choking or breakdown.

The maximum capacity of a 6-in., conveyor is about four tons of ash per hour; that of the 8-in., six to nine tons; and of a 9-in. conveyor, ten to fifteen tons and even twenty tons in some cases. The capacity depends largely upon the size of the pieces. Ash should not be wet or quenched when fed to an air conveyor. Ashes can be conveyed

by air conveyors through a horizontal distance of about 500 ft. and through a rise of about 100 ft.

The cast iron used for pipes and elbows and other fittings is generally made of the hardest possible white iron, such as is not machinable and can only be ground, so that connections are commonly made by means of bolts slid into open lugs. The wear is greatest at elbows where the ash direction is changed, and it is usual to provide "wearing backs" of easily replaceable blocks.

Air conveyors use a large quantity of steam while running; but as they remove the ash very rapidly, the cost of steam per ton of ash removed is quite small when they are properly operated.

Considerable expense ensues if steam nozzles are allowed to wear excessively before renewal. Not only is the steam consumption greatly augmented, but the increased energy of the larger steam jet results in higher air and ash velocities with greater wear of pipes, elbows, targets, etc. Such wear of steam nozzles is greatest with wet steam.

In some instances the steam-jet conveyor is objectionable because the steam used represents so much water lost, and which must be replaced by "make-up." It is becoming increasingly general practice to distill all make-up water so as to prevent any scale-forming or foam-making salts from getting into the boilers. Condenser leakage is diligently looked for and eliminated. Therefore, owing to the care with which pure water must be conserved, it is obvious that any apparatus which removes water from the system, such as steam jets whose steam does not eventually reach the condenser, will usually be frowned upon by operating engineers.

One ton of steam will move four to eight tons of ash. With a coal containing 12 per cent of ash, two tons of steam would be used per 100 tons of coal. Taking an average evaporation of 9 lb. of water per pound of coal, the conveyor would use two tons of steam out of each 900 tons generated or nearly 0.2 per cent. To allow for careless operation or negligent maintenance and other contingencies, it would perhaps be advisable to allow, say, 0.3 or 0.4 per cent in arranging for extra distillation for make-up.

Air conveyors generally result in clean basements or firing floors because there is less spillage. The first cost is usually lower than that of a mechanical system, they take up very little space and can be installed in awkward positions, and require very little attention; but this is not always a good feature unless periodical inspection is conscientious, because steam nozzles may wear and leaks due to abrasion of pipes develop, and these may result in considerable waste of steam. The very convenience of the method may develop carelessness in allowing the steam to blow when ash is not being fed. It is safe to operate because there are no moving parts and this feature makes also for small expense of putting in renewals.

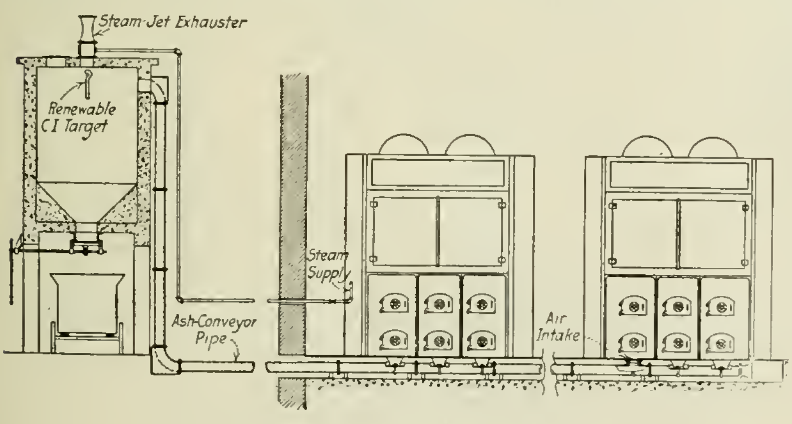

Fig. 17 Air Conveyor with Vacuum Storage Tank

The air conveyors which are being installed by the Conveyor Corporation of America at the New Milwaukee sewage plant are illustrated in Figs. 18 and 19. The plan in Fig. 18 shows the ash conveyor, which has a bore of 9 in., in conjunction with the four 734-hp. stoker-fired boilers. The hopper ashpits are dumped into auxiliary hoppers formed about the conveyor intakes, as will be seen in Fig. 19. This permits of rapid feeding of the conveyor

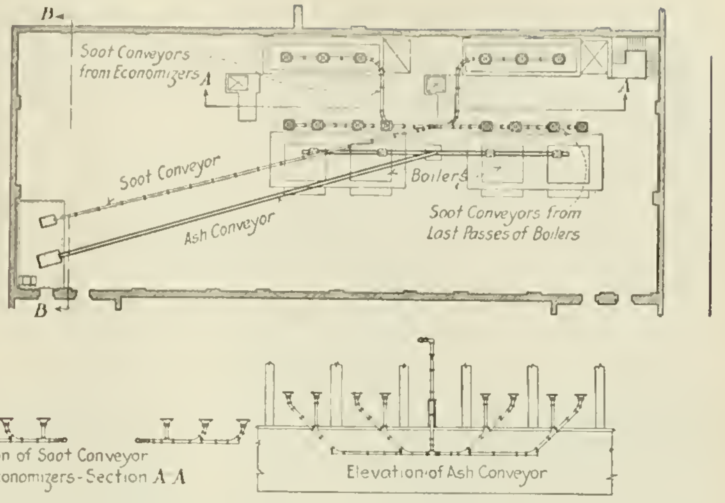

Fig. 18 Air Conveyor at Milwaukee Sewage-Disposal Power Plant. Plan

without smothering it. It is to convey a minimum of 12 tons per hour, with a steam consumption not exceeding 325 lb. of steam per ton of ashes.

The conveyor for soot and fly ash is independent of the ash conveyor and has a bore of 6 in. This arrangement usually increases both the capacity and the efficiency over that obtained with combination conveyors. It is connected to the later boiler passes and to the economizer, and discharges into a separate target box set upon the top of the ash bunker.

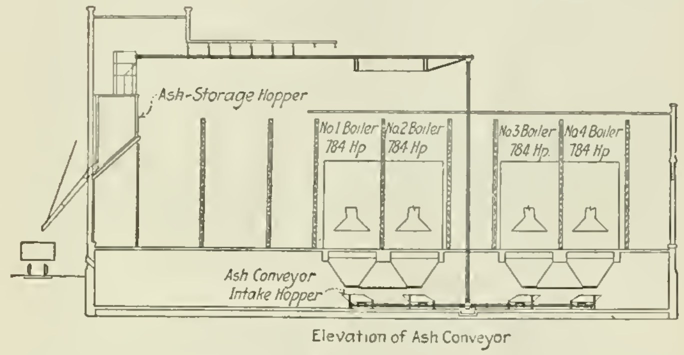

Fig. 19 Air Conveyor at Milwaukee Sewage-Disposal Plant. Elevation

The installation at the Lakeside plant of the Milwaukee Electric Railway and Light Company is of considerable interest because the boilers are fired with pulverized coal. See Fig. 20. There are eight boilers of 1333 hp. each—1306 hp. in the boiler proper and 27 hp. in the form of a water screen at the bottom of the combustion chamber. This water screen entirely prevents the formation of clinker or slag which was so troublesome in some of the earlier powdered-coal installations. Instead, the ash from the combustion chamber is a fine powder which is very easily handled by an air conveyor.

The air conveyors were installed by the Vacuum Ash and Soot Conveyor Company, have been in successful operation nearly two years, and practically no maintenance work has been required during that time; only one nozzle has been replaced.

To recover some of the fine ash which would otherwise be discharged from the chimney top, a smoke washer is installed in the main flue about twenty feet before it enters the base of the stack. It consists of two 4-in. pipes placed parallel to each other in the top of the flue. These pipes are provided with nozzles of $^1/_4$-in. pipe 1 in. long placed at 3-in. centers along each pipe, the nozzles of one pipe being staggered relatively to those of the other. The pipes are supplied with about 350 gal. of water per min. at a pressure of about 6 lb. per sq. in. The jets from the nozzles form a water curtain through which the gases must pass before entering the chimney.

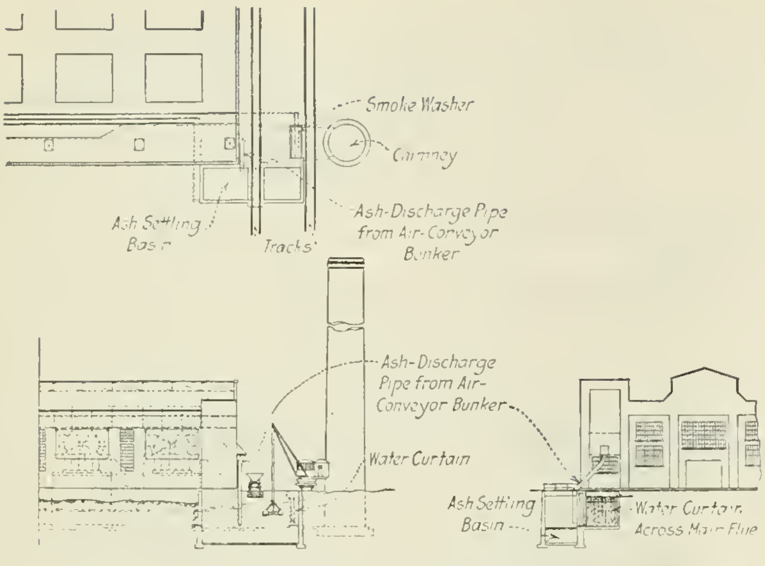

Fig. 20 Air Conveyor and Smoke Washer for Pulverized-Coal Firing at Lakeside Station, Milwaukee

Actual tests show that 50 per cent of the ash suspended in the flue gases is removed by this apparatus.

The boilers are arranged in two rows of four each, facing each other across the firing aisle. There are two conveyors, the main line of each being in the floor of the ash alley in front of the furnace ashpits. Each main line takes care of four boilers. Branch lines lead to the ash chambers at the rear of the boilers and also to the ashpits under the economizers.

All the conveyor lines are of 8-in. cast-iron pipe. The running length of the two main lines is approximately 200 ft. with a vertical rise of 65 ft. The lines from the ash chambers and the economizer ash hoppers are approximately 190 ft. long and have a vertical rise of 50 ft.

Ash Bunkers

Considerable choice of materials and design of ash bins and supports is available. A large number, perhaps most, are made of reinforced concrete. In some cases they are inside the boiler room and worked into the general design of coal bunkers, etc., such as illustrated in Fig. 14. They are occasionally built so as to span an alley, being supported by the buildings on each side.

Ash bunkers have also been built of brick, but unless very thick walls are used, they should either be buckstayed or have reinforcing bands laid up every five or six courses. The bricks should be hard and well burned, and laid in cement. The inner face of the walls should be of paving brick.

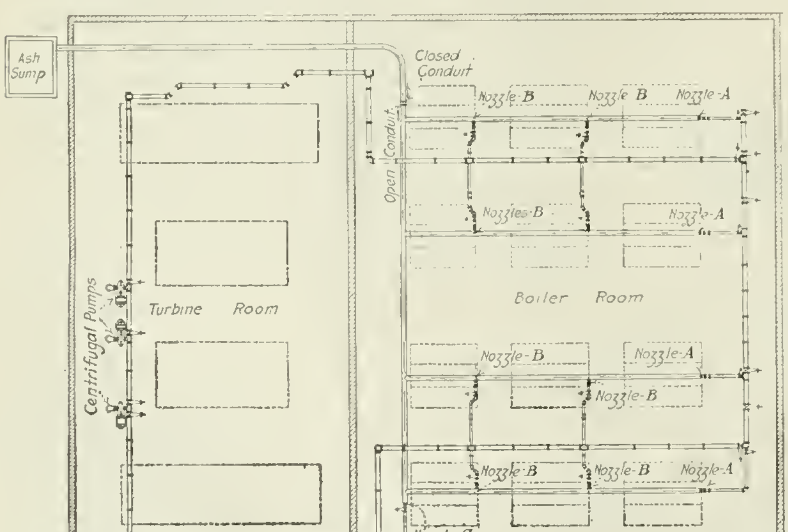

Fig. 21 Water Conveyor at Hell Gate Station. Plan

Hollow-tile ash tanks have several inherent advantages in that they are fireproof, prevent freezing of wet ash, are acidproof provide space for steel reinforcing rings within the wall, and have a smooth interior surface. The tiles are laid up in cement and are provided with key grooves on their joint faces.

Tanks may also be made up of a cast-iron skeleton filled in with cast-iron plates, the whole carried on a structural-steel framework. Cast iron, being much less subject to corrosion than steel, makes a durable tank for ash storage.

Water Conveyors

In systems of water conveyance the conduits carrying water are largely or wholly open. With a plentiful supply of water, this method has much to recommend it. There is no dust or heat and the ashes are carried away very quickly. Owing to the low velocity of the vehicle as compared with air, the wear is very small and usually is not troublesome. The conveyance, of course must always be down hill when open flumes are used, and a grade of 3 or even 4 per cent is desirable.

Where a natural supply of water from an elevator is not available a centrifugal pump may be used. The Hell Gate plant is an excellent instance of this kind, and the general layout is shown in Fig. 21. This is a system of open flumes within the boiler room continuing through a closed pipe to the ash setting tank. Tributary flumes are carried along below each line of boilers and empty into a main cross-flume which runs along the boiler room wall near the turbine room. This main flume then turns and becomes a full pipe or enclosed conduit leading to a pit near the river side into which it discharges. The ashes are recovered from this pit by a grab bucket operated by a locomotive crane running on a track laid on the pier, and discharged into scows. The scows are towed out and dumped at sea about five miles east of Sandy Hook, or about thirty miles from the plant.

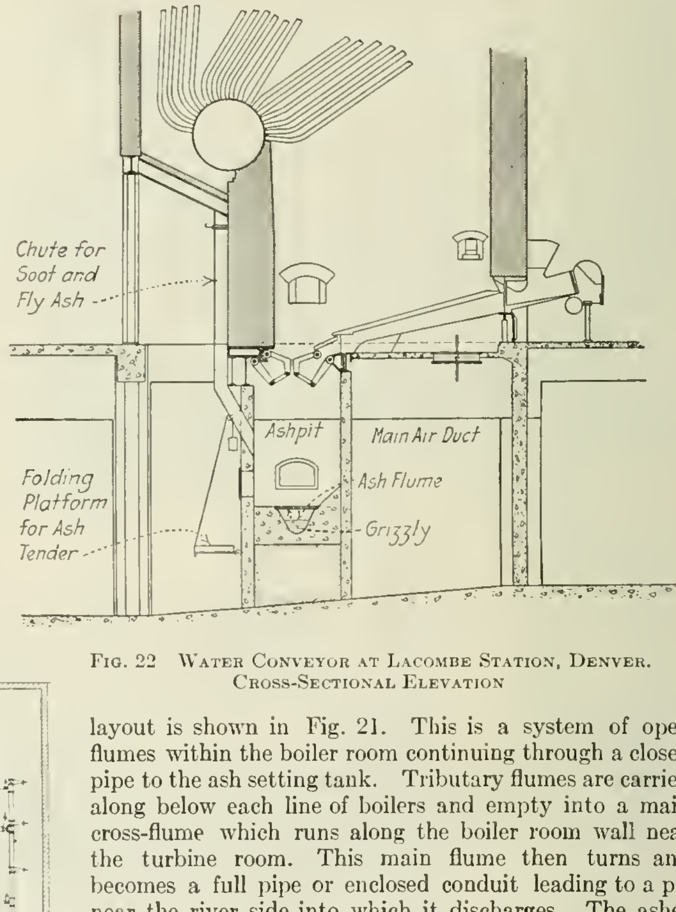

Fig. 22 Water Conveyor at Lacombe Station, Denver. Cross-Sectional Elevation

The flumes within the boiler room are of concrete with a bottom lining of vitrified earthen drain tiles or half-pipes. Those under the boilers are supported on structural-steel framework suspended from the firing floor, while the main cross-flume is carried on steel trestling.

A cross-section of the flume under the boilers is shown in Fig. 23. The ash as it leaves the clinker grinders drops directly into the water and is carried away. Access doors lined with common brick are provided so that any ob-

struction can be handled easily. These doors may be seen in Fig. 23.

The method of water supply is very interesting. There is a nozzle *A* at the head of each tributary flume, and an ingeniously arranged undercurrent nozzle *B* at the beginning of each succeeding ashpit. These undercurrent nozzles are at the bottom of the flume and are arranged to discharge horizontally downstream. They are placed to form steps in the flume so that the ash flows over them. At the head of the main conduit is a booster nozzle *C*.

The water for the various nozzles is taken from the circulating discharge tunnel and is supplied under pressure by 12-in. Lea-Courtenay centrifugal pumps direct-driven by 150-hp. Westinghouse motors. These pumps supply 5000 gal. per min. against a head of 75 ft., operating at 81.5 per cent efficiency.

The main pipe line which supplies the water nozzles has a bore of 16 in. and is arranged as a ring as clearly shown in Fig. 21.

Fig. 22 shows a cross-section of the flume under the boilers of the Lacombe station of the Denver Gas and Electric Light Company. The outstanding difference between this plant and the one at the Hell Gate station is that there are no clinker grinders. As a result, the flumes are protected by a "grizzly" composed of heavy bars set 6 in. center to center to withstand breaking up the large clinkers until they can drop between the bars into the flume. The water stream will easily handle clinkers about 12 in. square and 15 lb. in weight.

Water sprays cool the clinkers which are caught on the grizzly. Side-hinged doors 18 in. by 23 in. are provided through which the clinkers can be managed.

The station contains five boilers of 750 hp. each, operated at 250 to 300 per cent of rating. The coal is a sub-bituminous containing 6 to 7 per cent of ash. As the boilers are in line, the flume is single and straight. It is all of 2 per cent grade except the curve to the ash-settling tank, which is of 18-in. vitrified sewer pipe laid horizontally. The flume and sewer pipe is about 155 ft. total length. The capacity of the setting tank is 3000 cu. ft.

The water passes through a screen and is recirculated, and a 2-in. line is used to replenish occasionally the water in the system. The water is circulated by a 6-in. American open-runner centrifugal pump driven by a 20-hp. motor. The pump delivers about 1100 gal. per min. against a head of 25 ft. The system deals with about 33 tons of ashes in 24 hours.

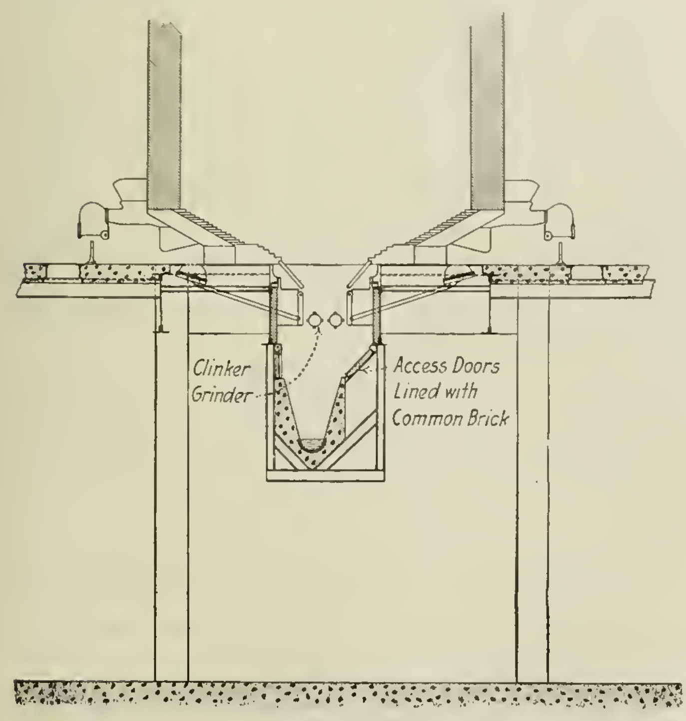

Fig. 23 Water Conveyor at Hell Gate Station. Cross-Sectional Elevation

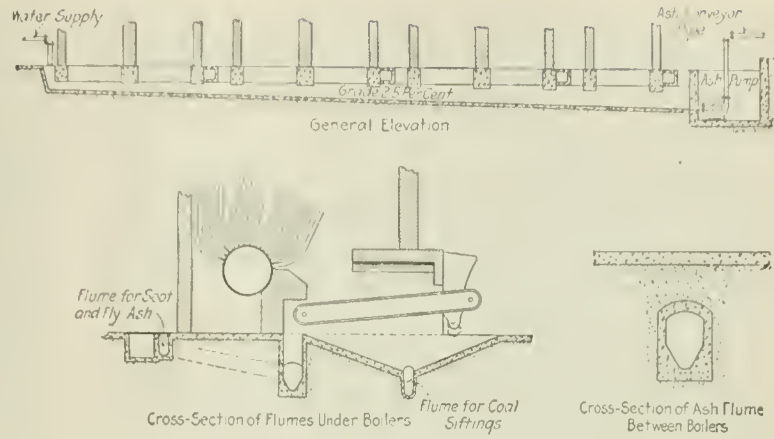

Fig. 24 Morrison's Water Conveyor at Great Western Sugar Refinery, Denver

An ingenious arrangement is that invented and patented by Mr. Morrison, of the Great Western Sugar Company of Denver, and installed in several of their plants. An example is partly illustrated in Fig. 24. A flume into which the ashes are fed is arranged under the boilers as in other water conveyors. This flume carries the ash-laden water into the suction connection of a centrifugal pump which discharges into the conveyor pipe. The conveyor pipe is of cast iron, 6 in. bore. Abrasion occurs slowly, but is confined to the bottom of the pipe. It is found that by rotating the conveyor pipes through an angle of 90 deg. every few years, maximum service is obtained out of each renewal.

In designing a water conveyor it must be borne in mind that while continuous dumping stokers such as chain grates or those equipped with clinker grinders may discharge dirctly into continuously running water, dumping stokers or any firing system where large clinkers are to be expected should discharge on to a grizzly of massive bars on which clinkers may be broken small. The water need only be running while dumping is in progress with stokers of the dumping type.

Concrete troughs, if carefully built, will be found to require very little repair. The inside lining should be smooth and free from pits. There should be a plentiful supply of water under a few pounds pressure. About 1000 gal. per min. should be supplied for each flume.

With natural draft, means should be devised to provide seals so as to prevent too great an excess of air from passing up through stoker dumps.

When the water is recirculated, the pump should be designed to handle gritty water, and occasional renewals due to this reason must be expected, though they will not be serious.

As there is often considerable dust and gas generated with stokers of the dumping type, it is advisable to provide the access doors with latches so that they cannot be blown open. Ample ventilation near where ashes are handled should always be provided.

In some localities in winter, trouble may be expected from water freezing in the bearings of grab buckets. In particularly cold situations the wet ash will freeze in the cars and cannot be dumped unless it is thawed out. Weather conditions may therefore prohibit water conveyors in some instances.

Discussion

In OPENING the extensive and extremely interesting discussion which followed the presentation of the paper, T. A. Marsh[1] said he would like to emphasize the serious effect of small ashpits and ash hoppers on stoker maintenance. Aside from the question of draft, he said, there was no one item which had caused more stoker failures than ashpit design. The cross-bar conveyor in water, shown in Fig. 16, had acquired great popularity in this country and he saw great possibilities for it. As the economic capacity of a man handling ash from an air conveyor was five to six tons, he saw no necessity of using larger than an 8-in. conveyor system. The remote-control steam valve for air conveyor systems, mentioned in the

[1] Chief Engineer, Green Engineering Co., East Chicago, Ind. Mem. Am.Soc.M.E.

paper, for shutting off the steam when the conveyor was not in use, was being received with great favor, and it appeared that the steam consumption of the average air conveyor might be cut in two by the use of this valve. It was very important, he said, to emphasize the author's caution in regard to keeping down the wear of steam nozzles in such systems.

F. B. Allen[1] discussed the design of ash hoppers which were bottom-dumped by means of power-controlled gates, discharging into some type of car beneath. It was essential for operating reasons, he said, to quench the ashes before dumping. The ordinary system of quenching by introducing one or two pipes perforated with holes was unsatisfactory as an excessive amount of water, with attendant difficulties, was essential for effective quenching. He then described, with the use of lantern slides, how better results could be obtained by running the quenching-water header outside of the hopper with a series of offtakes to quenching nozzles located through the hopper walls. Each quencher sprayed water in fine particles over the ash, and could be independently controlled and cleaned from the outside. He also gave particulars regarding the gates of this type of hopper.

R. H. Beaumont[2] said that in his opinion an ash-handling system should be capable of meeting the following conditions: (1) It must be capable of handling very large clinkers; (2) it must be of such design that abrasion has little or no effect on its parts, so that repairs are negligible; (3) it must not consume much power, nor waste it running idle; (4) it must be capable of lifting ashes to a good height without being subject to excessive wear by so doing; (5) it must handle either red-hot or dripping wet ashes with equal facility; (6) it must operate without making dust or exceptional noise; (7) it must have a high hourly capacity; (8) it must handle the general run of boiler-room refuse, such as soot, flue dust, broken bricks, grates, etc.; (9) it must accommodate itself to plant extension without complete remodeling; and (10) it must deliver ashes into a storage bunker so that they are acceptable as railroad freight. He described also the automatic electric skip hoist, which he considered the most important device used today in the handling of ashes.

Nevin E. Funk[3] said that ash-handling systems could be divided into two classes: those easy to operate and easily repaired without putting the entire apparatus out of commission; and those with no flexibility at all, which put at least one section of the boiler room out of commission in event of failure, and which cannot be aided by some crude makeshift in time of failure. In the first class he put the railroad car, the industrial railway with storage battery or trolley locomotives, and possibly the water-sealed ashpit of Fig. 10. In the second class he included all mechanical, air, and hydraulic conveyors. The use of railway cars did not mean raising the boiler room much more than required by many other schemes. He pointed out that even with a continuous ash-disposal system there must be sufficient storage to take care of periods of breakdown. He criticised a system which was used for both coal and ash because of the chance of getting ashes in the coal. He did not like the water-seal chain and cross-bar conveyor of Fig. 16 because of the liability to breakage. Even with two such systems parallel the breakage of one might easily result in the breakage of both; and it would not be easy to make repairs to such a system while the boilers were in operation. Speaking of the air-conveyor system with vacuum storage tank shown in Fig. 17, he said that there was danger of an explosion in such a system as gas might easily be generated in the tank. He was sure that hydraulic systems, even those depending upon flotation, would soon wear out due to abrasive action of the water and ashes.

Nixon W. Elmer[4] spoke of the problem of ash disposal in a powdered fuel plant.

I. E. Moultrop[5] said that of the three great handling problems in the power plant-handling water, coal, and ashes—that of handling ashes was the greatest. He spoke of the cost of disposing of the ashes after they had been removed from the power plant. A very large ashpit, he said, was absolutely essential. Ashes should be taken away with the use of as little machinery as possible, as one did not want machinery which, in case of breakdown, would interfere with the removal of ashes. He agreed with Mr. Funk that the best scheme was the industrial or steam railway because, in case of breakdown, the ashes could be dumped on the floor, later to be carried away.

[1] New York City.

[2] Pres., R. H. Beaumont Co., E. Chicago, Ill. Mem. Am.Soc.M.E.

[3] Operating Engineer, Philadelphia Elec. Co., Philadelphia, Pa. Mem. Am.Soc.M.E.

[4] Cons. Conveyor Engineer, Quincy, Mass. Mem. Am.Soc.M.E.

[5] Asst. Supt. Construction Bureau, Edison Elec. Illum. Co., Boston, Mass. Mem. Am.Soc.M.E.

T. Maynz[1] spoke of the necessity for ash storage space. In his plant an industrial railway with skip hoist to storage had been installed. In case of breakdown the ashes are dumped on the floor. The problem, he said, was not to cut down the head room of ashpits, but to give them all the room possible.

Sam H. Libby[2] spoke of some of the difficulties confronting the designer of hoists for ash-handling systems which resulted from incomplete or incorrect information about the details of what was expected of his designs.

E. H. Tenney[3] wrote in part: "In connection with the use of air ejector systems in downtown districts we found that, other things being equal, a great deal of consideration had to be given to the prevention of dust. In the particular installation in mind this was eliminated by the careful design of water spray rings and the proper installation of a standpipe vent on the ash-receiving tank. We have also found that where ash hoppers are located outside the plant so that trucks or other conveyances can drive beneath them, for loading purposes, considerable difficulty was encountered in the winter time, due to the ash gates freezing. This difficulty was easily overcome by the installation of small steam lines on all such ash-hopper gates for the purposes of thawing them loose. This point should not be lost sight of in building overhead ash hoppers where the question of hurried ash removal is necessary, as is the case with office-building or hotel power plants."

Rankin Eastin[4] sent in a description of the ash-sluicing system which he had installed at the Tell City Water & Light Company, Tell City, Ind.

Charles E. Prout[5] described the G. & G. telescopic hoist which is adaptable to ash-removal systems in hotels and office buildings when the ashes must be elevated to the street from a boiler room below ground level. This system was applicable, he said, to two conditions found with such types of building: those in which a wagon or railway car could be brought alongside and the cans emptied without removing them from the hoist, and those in which the cans could not be dumped without removal. The average can, he said, weighed about 150 lb. and could be elevated and returned to the basement at a speed of 60 ft. per min.

Eugene Hahn[6] presented an extensive discussion of the problem of removing ashes on shipboard.

George G. Bell[7] presented a written discussion in which he showed how the necessity of ash-handling equipment became acute when coal of high ash content and low fusing temperature was used for power purposes. He spoke also of the difficulty of proper quenching of the cinders and of the gases produced in the ashpit. He emphasized the need of a large ash-storage capacity to tide over difficulties with the ash-handling apparatus or with labor. He described, with lantern slides, the water-sealed type of ashpit originally proposed by Frederick Sargent for the Springdale plant and which was being installed in the extension of the Windsor plant of the West Penn Power Company.

In his closure to the discussion, John Hunter touched on some of the points brought up but said that he did not wish to enter into a detailed reply until he had an opportunity to do so in writing. He was sorry that his paper had been submitted to the printer before he had been able to include data on the G. & G. system which had been mentioned in the discussion.

[1] Test. Engineer, Cleveland Elec. Illum. Co., Cleveland, Ohio. Jun. Mem. Am.Soc.M.E.

[2] Managing Engineer, Hoist Dept., Sprague Elec. Wks., Bloomfield, N. J. Mem. Am.Soc.M.E.

[3] Chief Engineer of Power Plants, Union Elec. Light & Power Co., St. Louis, Mo. Mem. Am.Soc.M.E.

[4] Tell City Water & Light Co., Tell City, Ind.

[5] Adv. Mgr , Gillis & Geoghegan, New York, N. Y.

[6] Vice Pres. and Chief Engineer, Victor Engrg. Co., Inc., Philadelphia, Pa.

[7] West Penn. Power Co., Pittsburgh, Pa.

Stresses in Electric-Railway Motor Pinions

Determination of Their Distribution by the Photo-Elastic Method

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This paper embodies some results of a general scientific study undertaken by the General Electric Company for the development of superior electric railway motor pinions. The work described was performed at the Massachusetts Institute of Technology, using the General Electric Companys apparatus for stress determination in transparent models by the photo-elastic method. Some of the supplementary mechanical tests were made at Schenectady, and throughout the work close contact was maintained with the Railway Motor Department and the Research Laboratory at Schenectady. A brief description and discussion of the photo-elastic method is first given, following which the stress distribution in, and the causes of ruptures of, given types of gear pinions used in electric-railway motors, as investigated by the photo-elastic method, are reported upon and discussed.

THE state of stress at any point in a solid body is determined when the traction across every plane through the point is known. There exist at any point three orthogonal planes across which the traction is purely normal and which are called the planes of principal stress. The normal tractions across those planes are called the principal stresses. The state of stress at any point is completely determined by the direction and the magnitude of the principal stresses at the point under consideration. The principal stresses, given in direction and in magnitude, express in the most general and complete way the elastic state at any given point. The bending moment, the shearing forces, etc., are readily deduced from the direction and the magnitude of the principal stresses. Furthermore, one of the principal stresses always expresses the maximum stress.

The notion of principal stress may be illustrated as follows:

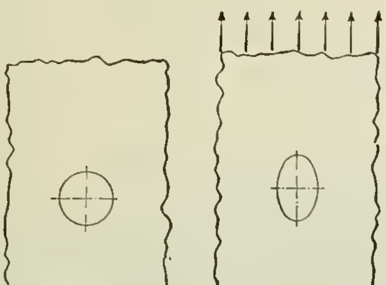

FIG. 1 ELLIPSOIDAL ELEMENT RESULTING FROM SUBJECTING A SPHERICAL ELEMENT TO STRESS

Consider a spherical element in a solid body. External applied loads will deform this spherical element into an ellipsoidal element (Fig. 1). The axes of this ellipsoid will correspond in direction and in magnitude to the direction and the magnitude of the principal stresses.

The orientation and the form of the ellipsoid and therefore the direction and the magnitude of the principal stresses, will define the state of stress at the point under consideration.

The axes of the ellipsoid represent the largest and the smallest deformation at the point under examination. Correspondingly, the principal stresses give the direction and the magnitude of the maximum and the minimum stress.

If the three principal stresses vary from point to point in the structure, the problem to be dealt with is a three-dimensional elastic one. If one of the three principal stresses vanishes throughout, it is a two-dimensional elastic or plane-stress problem.

Corresponding to the three- and two-dimensional elastic-stress problems there are also the three- and two-dimensional elastic-strain problems, when the deformations corresponding to the principal stresses are considered.[1]

A great number of structural problems (bridge, ship, airplane, plate, dam, etc., construction) are, or their stress analysis may be reduced to, two-dimensional elastic problems.

THE PHOTO-ELASTIC METHOD OF STRESS DETERMINATION

As set forth at the beginning of the paper, the state of stress at any point is most completely defined by the direction and the magnitude of the principal stresses. These are, therefore, the elements which we wish to determine for a complete analysis.

The photo-elastic method solves the two-dimensional elastic problems. It primarily takes advantage of the double refracting properties shown by isotropic transparent substances when put under stress. The stresses in the structure may therefore be determined from models made of a homogeneous transparent material, and ordinarily on a reduced scale. The stresses in a steel, cement, or any other structure, homogeneous throughout and obeying Hooke's law of linear proportionality between stress and strain, may be readily deduced from the values obtained by the analysis of the corresponding transparent model for the case of two-dimensional elastic problems.

FIG. 2 REPRESENTATION OF COLORED IMAGE WHEN BOTH NORMAL INSIDE PRESSURE AND MAXIMUM TORQUE ARE APPLIED

(The darkest portions of the image reproduced above are purplish in the original; the next lighter portions, bluish green; the next lighter, reddish orange; and the lightest, yellow.)

If plane polarized light is passed through a stressed specimen of celluloid and afterward through a second nicol prism whose principal section is parallel to the plane of polarization of the original beam of light, only the points where the principal stresses are respectively parallel and perpendicular to the principal sections of the crossed nicols remain dark. The result makes it possible to determine the directions of the principal stresses at any given point.

If now circularly polarized light be passed through the specimen, by interference of the two component rays, which in the double-refracting specimen have suffered a relative retardation at each point proportional to the difference in magnitude of the two principal stresses, a colored image is obtained. Practical considerations make it impossible to reproduce these colored images here, but an idea of their general appearance may be gained from Fig. 2.

By a comparison method, based upon the interposition in the proper direction of a comparison member of constant cross-section, put under uniform tension in a suitable frame (Fig. 3), the value of the difference of the principal stresses at any given point may be read on the dynamometer of the frame.

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Presented at the Annual Meeting, New York, December 4 to 7, 1922, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Abridged. All papers are subject to revision.

[1] A complete theory of stress and strain may be found in the Treatise on the Mathematical Theory of Elasticity by A. E. H. Love, 3rd ed , chapters i-iv.

Now, in the two-dimensional elastic problems the transverse deformation, i.e., the deformation along a normal to the plane of the two principal stresses, is proportional to the sum of those two stresses.

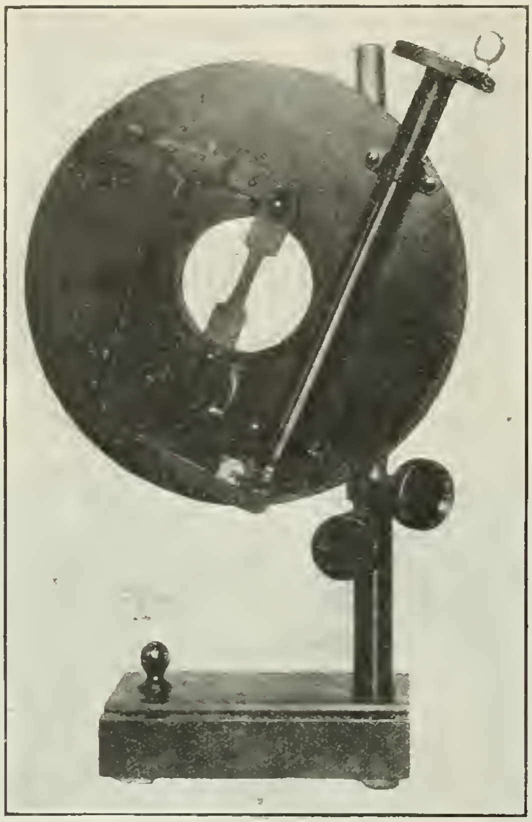

Fig. 3 Frame for Comparison Member Designed by E. G. Coker and A. L. Kimball, Jr.

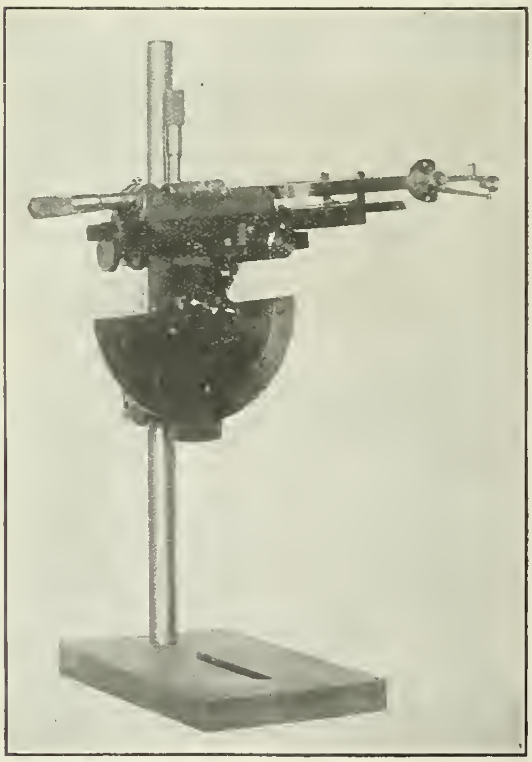

Fig. 4 Lateral Extensometer Designed by P. Heymans

By means of a lateral extensiometer, Fig. 4, we measure this transverse deformation. From the values of the differences and the sums of the principal stresses, the separate values of each of them are computed, thus determining completely the state of stress.

A question naturally arising is whether the results obtained on a transparent body such as celluloid hold for structural materials. It is shown by the general discussion of the equations of elastic equilibrium that in the case of strain or plane stress in an isotropic body obeying Hooke's law of linear proportionality between stress and strain, the stress distribution is independent of the moduli of elasticity and consequently of the material of which the body is made. Thus the stress distribution experimentally determined in the case of a celluloid body is the same as it is when the body is made of any other isotropic substance such as iron, steel, etc., obeying Hooke's law, in distribution, direction, and magnitude. Moreover these conclusions derived from the general theory of elasticity have been checked by experiment.

The photo-elastic method can be applied to the great majority of structural problems, not only in taking the place of mathematical computation, but particularly in solving those structural problems where mathematics becomes too involved to be of help. Moreover it has the great advantage of giving the maximum stress at each point throughout the whole structure, and it therefore offers an effective means of increasing safety and reducing superfluous material.

Stress Distribution in Gear Pinions

When accidents occur with gear wheels, besides the metallurgical question, three possible causes of failure suggest themselves:

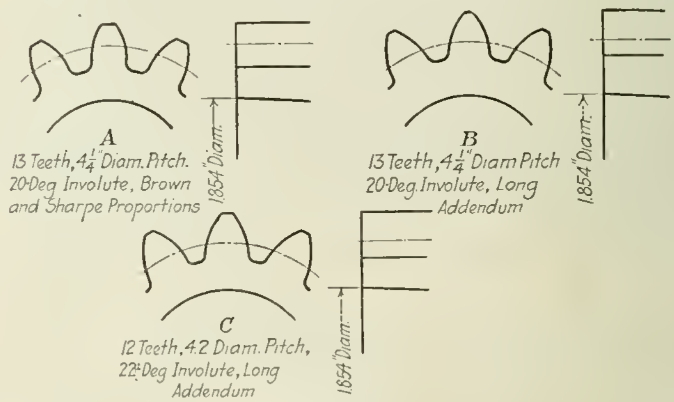

Fig. 5 Tooth Forms of Pinions Subjected to Photo-Elastic Analysis

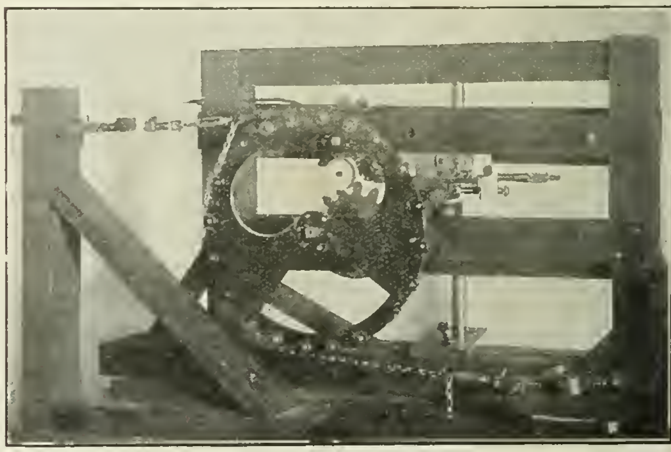

Fig. 6 Frame Used for Applying Loads to Celluloid Models of Pinions

a The gear wheel may not have been properly designed
b It may have failed under an excessive load
c When the pinion was shrunk hot or forced on to a tapered shaft, an excessive inside radial pressure may have been set up.

It is easy to see that the ordinary methods of resistance calculation of gear wheels, based on considering the tooth as a cantilever loaded at its end, would not be expected to give reliable and complete information as to stress distribution, not even for the root section of the tooth which is under consideration.

Fig. 7 Steel Rings Ruptured by Being Forced on to a Tapered Plug

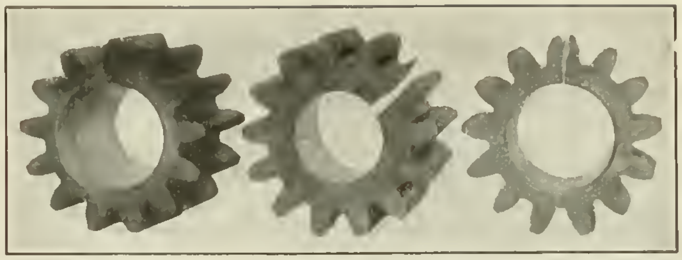

Fig. 8 Steel Pinions Ruptured by Being Forced on to a Tapered Plug

Indeed the shape of the tooth, the curvature at the root, the ratio of the diameter of the pinion bore to the root and outside diameter, the permanent stresses introduced by the placing of the pinion on the shaft, etc., all affect the stress distribution and the maximum stress. Photo-elastic analysis shows that these factors affect the stresses considerably more than would be expected from present methods of estimating. For standardized pinions the correction coefficients can only partially take account of these factors. For special pinions or for pinions of which more efficient running is required, a photo-elastic analysis seems to be the best if not the only effective way to determine the stress distribution and to locate the maximum stress.

Certain interesting points have been brought out by photo-elastic analysis which have been checked by tests carried out on steel sections. These are particularly interesting because they were unexpected.

Besides the stress distribution in the different sections of the pinions represented by Fig. 5 the photo-elastic analysis has given as maximum stress under normal inside radial pressure and normal torque:

80,000 lb. per sq. in. for tooth form *A*
70,350 lb. per sq. in. for tooth form *B*
60,900 lb. per sq. in. for the tooth *C*.

Moreover the 12-tooth pinion shows, besides a smaller maximum stress, a better stress distribution. Fig. 6 represents the frame used for the loading of the models. A tapered expansion ring is used to produce the radial inside pressure. The torque is measured by properly mounted dynamometers.

For steel pinions the maximum stress attained under normal conditions, although high, appears not to be excessive. *Tooth C appeared to be a better design* under normal conditions.

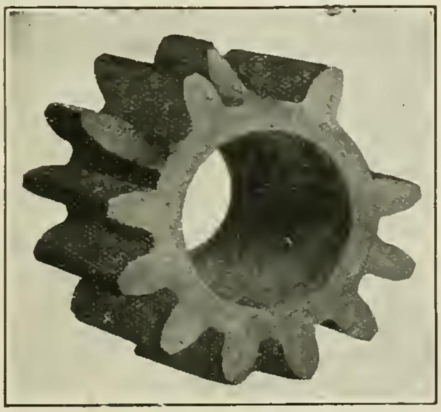

Fig. 9 Fatigue Failures of Teeth Produced by Experiment (with Radial Pressure in Bore)

The stresses due to shrinking or forcing the pinion on the shaft can only be estimated. The pinion may be assumed to be a plain circular ring, for which case the stresses may be mathematically computed. The stress at any point of the ring as well as the maximum stress in the ring depends upon the lengths of the inside and outside radii. The opinion generally expressed is that for the case of the pinion the maximum stress will be intermediate between the maximum values obtained for rings of which the outside diameters are respectively equal to the root diameter of the tooth and to the outside diameter of the pinion, the inside bore being the same.

Photo-elastic analysis shows that *the gear pinion is even weaker than the plain circular ring whose outside diameter is equal to the root diameter of the tooth.* The change of external profile, due to the presence of the teeth, although requiring an addition of material, weakens the structure.

Figs. 7 and 8 show the steel specimens after having been tested by forcing a tapered plug into the bore; and Table 1 gives the rupture load applied to the tapered arbor forced into the bore for the different specimens. These confirm the photo-elastic results.

Previous to the photo-elastic investigation of the stresses due to radial inside pressure in pinion sections, fracture due to pure radial inside pressure would have been expected to occur through the minimum radial cross-section.

From the color image obtained in the photo-elastic analysis when normal inside pressure alone was applied, it appears that *the regions under the teeth are under higher stress* and that the points at the inside boundary right under the teeth are points of maximum stress. The regions in question in the color image mentioned are similar in appearance to the region *A* in Fig. 2.

TABLE 1 RUPTURE LOAD ON ARBOR FORCED INTO SPECIMENS TESTED

	Inside diam., in.	Outside diam., in.	Root diam., in.	Rupture load, lb.
Ring	1.854	3.5	...	85,000
Ring	1.854	2.5	...	51,000
Pinion	1.854	3.5	2.5	47,000

Fig. 8 gives the fractures obtained on steel sections. Two of the sections show fractures right through the thickest layer of material, while all of them started at points where the photo-elastic analysis had revealed maximum stress. The uneveness of the material must account for the deviation of the fracture in one of the cases.

Can any statement be made as to the causes of the failure by inspection of the shape of the fracture? In the case in which the authors were interested, the photo-elastic analysis determined the best design. As before said, either the placing of the pinion on the shaft, if carelessly done, for instance by pounding the pinion heavily on the tapered shaft, or excessive torque and blows due to sudden meshing or the taking on of a heavy load, will set up dangerous stresses.

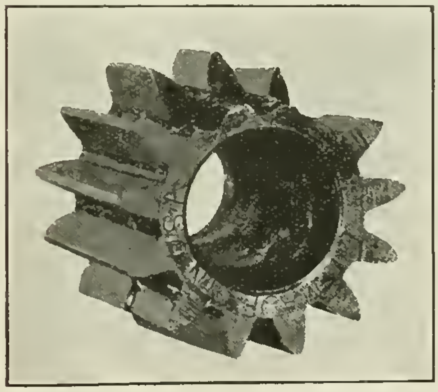

Fig. 10 Fatigue Failures of Teeth Produced by Experiment (with Heavy Radial Pressure in Bore). Note Fracture is of an Open V-Shape

The authors' photo-elastic analysis has shown that *the sections of dangerous stresses are different for different values of inside radial pressure and applied torque load.*

The fracture shown in Fig. 9 is of an *open* V-shape. Photo-elastic analysis shows that *the higher the inside radial pressure becomes,* for a given torque load, *the sharper becomes the V-shape of the section of dangerous stresses.* (Fig. 10.) If the fracture is due to too high a torque load the angle of the V will approach 180 deg. Tests on steel sections have been made with a specially built impact machine.

Without inside radial pressure the fracture obtained is a straight line through the root section of the tooth. With increasing pressures the V-shaped fracture becomes sharper. For an inside radial pressure exceeding the elastic limit, however, the observation does not hold. The reason for this departure from what the photo-

(*Continued on page 137*)

Torsion of Crankshafts

By S. Timoshenko,[1] Philadelphia, Pa.

In order to apply the dynamics of elastic systems to the design of engines it is necessary to determine the torsional properties of the crankshaft. In the present paper the author considers the case of a crankshaft with a single throw and establishes the mathematical relations for such a case. He investigates three conditions of such a crankshaft: (1) no constraint, corresponding to ample clearance in the bearings; (2) complete constraint, corresponding to no clearance in the bearings; and (3) partial constraint, corresponding to ample clearance in the halves of the bearings nearest the web and no clearance in the other halves.

Engine design no longer comprises merely the application of statics, more attention being now paid to the fact that in various types of engines there is not even an approximation of a state of equilibrium. If there are variations in the torque and in the magnitudes of the force, they are necessarily cyclic, and as such they produce cyclic changes in the state of motion and deformation of the parts. The problem is no longer one of statics, but concerns the dynamics of an elastic system. Variations in the state of motion are associated with inertia forces, and the stresses in the various parts of the engine are no longer due to the actually impressed forces alone. Obviously, calculations which consider only the impressed forces must lead to erroneous results, and frequently a break occurs where the designer thought there was an ample margin of strength. Moreover cyclic changes in the state of deformation of a crankshaft, for example, bring about a cyclic change in the orientation of the various cranks, and the balance of the reciprocating parts, which may exist without such changes, is totally destroyed. With reciprocating engines the cyclic changes in the state of motion, referred to above, concern principally changes of the velocity of rotation. In order to apply the dynamics of elastic systems to the type of engine just mentioned, it is necessary to determine the torsional properties of the crankshaft. This is the object of the present paper, which deals with the simpler cases and will be followed by another discussing the two- and three-cylinder two-bearing crankshaft, the multi-throw crankshaft, and the effect of clearances in the bearings.

On account of the very complex structure of reciprocating engines, the calculation of the torsional vibrations in their crankshafts is impossible without making some simplifying assumptions: namely, that certain parts, such as shafts, are considered to be elastic, and others, such as flywheels, armatures of generators, etc., are considered to be absolutely rigid. With these assumptions the engine may be reduced to a system of flywheels situated on a shaft of uniform diameter. This shaft is called the "equivalent shaft;" its diameter may be chosen arbitrarily, but its length between each two flywheels must be such that it is equivalent as to torsion to the actual shaft between corresponding parts of the actual engine. That is to say, a given twisting moment M must produce the same torsional deformation in both.

The length of the equivalent shaft is called the reduced length l_0. If we denote by the torsional rigidity C of a shaft the product of the modulus of shear G into the quantity which measures its resistance to twist, then by elementary mechanics we have for the twist δ of a straight shaft of length l of whatsoever cross-section (provided it is uniform),

$$\delta = \frac{Ml}{C} \quad [1]$$

In the above, as well as in the following, angles will be expressed in radians and all other units in inches and pounds.

For a circular cross-section,

$$C = G\theta \quad [2]$$

wherein $\theta = \pi d^4/32$ is the polar moment of inertia of the cross-section.

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Contributed by the Research Committee and presented at the Annual Meeting, New York, N. Y., December 4 to 7, 1922, of The American Society of Mechanical Engineers. Abridged. All papers are subject to revision.

Similarly, we have for the equivalent shaft:

$$\delta = \frac{Ml_0}{C_0} \text{ and } C_0 = G\theta_0 \quad [3]$$

from which—

$$l_0 = \frac{C_0 l}{C} = \frac{\theta_0 l}{\theta} \quad [4]$$

As the foregoing shows, the calculation of the reduced lengths of the equivalent shaft has no difficulty for those portions of shaft in the actual engine which are straight. When the actual shaft is a crankshaft, however, the situation becomes very much more involved since it becomes necessary to determine the angular deformation δ brought about by a twisting moment M. Owing to the complex geometric shape of a crankshaft, these calculations can be accomplished approximately only. Various assumptions will have to be made, of which some are only roughly true. It is assumed that the throw is built up of component shapes whose deformations are totally independent of each other. Further, it is necessary to make certain assumptions about the nature and amount of constraint in the bearings. In the present paper only the single-throw crankshaft (Fig. 1) will be considered, and therefore the very considerable influence on it of the neighboring cranks will be neglected. Calculations will be made with three degrees of constraint.

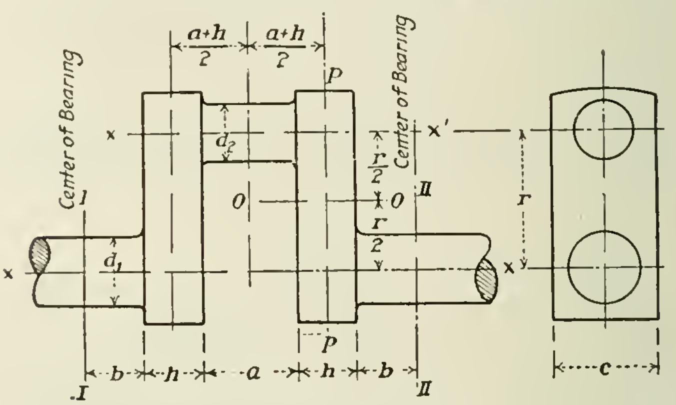


Fig. 1 Conventional Type of Single-Cylinder, Two-Bearing Crankshaft

Definitions and Symbols

Fig. 1 shows the conventional type of a single-cylinder, two-bearing crankshaft. In addition to the dimensions shown thereon, the following is a list of the definitions and principal symbols used in the paper:

Torsional rigidity, generally denoted by C, is the product of the modulus of shear G into the quantity corresponding to its resistance to twist. For a circular cross-section the latter is the polar moment of inertia of the cross-section in respect to the axis of twist. For a rectangular cross-section the quantity referred to is more complex. The formula usually used is only approximately true.

Flexural rigidity is similarly the product of Young's modulus into the quantity I corresponding to the resistance of the cross-section against bending. The latter is always the equatorial moment of inertia of the cross-section with respect to the axis of bending.

$C_0 = G\theta_0 = \frac{\pi}{32} d_0^4 G$ = torsional rigidity of equivalent shaft

$C_1 = G\theta_1 = \frac{\pi}{32} d_1^4 G$ = torsional rigidity of journal

$C_2 = G\theta_2 = \frac{\pi}{32} d_2^4 G$ = torsional rigidity of crankpin

$C_3 = G\theta_3$ = torsional rigidity of web in respect to twist around

O-O. Owing to the junction of journal and pin to the web, the latter's cross-section is not clearly defined, but in order to allow for local stresses at these junctions, at least in some measure, the assumption is made that the cross-section is a rectangle with sides r and c, whence—

$$\theta_3 = \frac{c^3 r^3}{3.6(c^2 + r^2)}$$

$C_3' = G\theta_3'$ = torsional rigidity of web with respect to twist around p-p. The cross-section is rectangular with sides h and c, whence—

$$\theta_3' = \frac{c^3 h^3}{3.6(c^2 + h^2)}$$

$B_1 = EI_1 = \frac{\pi}{64} d_1^4 E$ = flexural rigidity of journal

$B_2 = EI_2 = \frac{\pi}{64} d_2^4 E$ = flexural rigidity of crankpin

$B_3 = EI_3 = \frac{hc^3}{12} E$ = flexural rigidity of web against bending in the plane through p-p perpendicular to the plane of the drawing of Fig. 1.

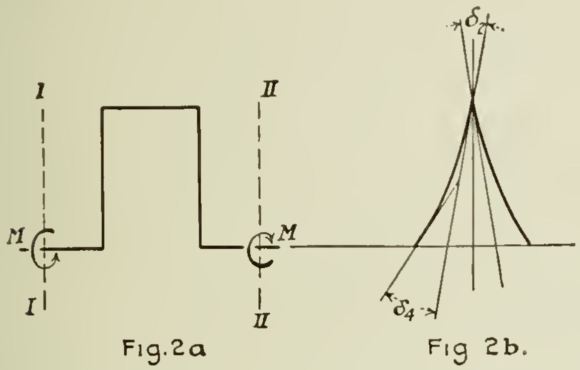


Fig. 2a Diagrammatic Representation of Single-Throw Crankshaft Before Deformation

Fig. 2b Diagrammatic Representation of Side View of Deformed Crankshaft

$F_1 = \frac{\pi d_1^2}{4}$ = area of cross-section of journal

$F_2 = \frac{\pi d_2^2}{4}$ = area of cross-section of pin

$F_3' = h \times c$ = area of cross-section of web taken on O-O

$F_3 = r \times c$ is taken to be the cross-section of the web on line p-p. This quantity is used in the calculation for the deformation due to shear in the plane through p-p perpendicular to the plane of Fig. 1. Similarly, as in the case of torsion, around O-O the cross-section is not clearly defined and $r \times c$ is used to allow for stresses at the junction of pin and journal to the web.

Case I—No Constraint, Corresponding to Ample Clearance in the Bearings

Fig. 2a is a diagrammatic representation of the throw before deformation with a twisting moment M applied at the middle cross-section of the journals. Fig. 2b is a side view of the deformed crankshaft. The total twist consists of the sum of the deformations of the portions b (see Fig. 1) of the journals, of the crankpin and of the two webs.

In the complete paper it is shown that—

$$l_0 = \frac{2bC_0}{C_1} + \frac{aC_0}{C_2} + \frac{2hC_0}{C_3} + \frac{2rC_0}{B_3} \quad \ldots\ldots\ldots\ldots [5]$$

Case II—Constraint at Bearings Complete, Corresponding to No Clearance

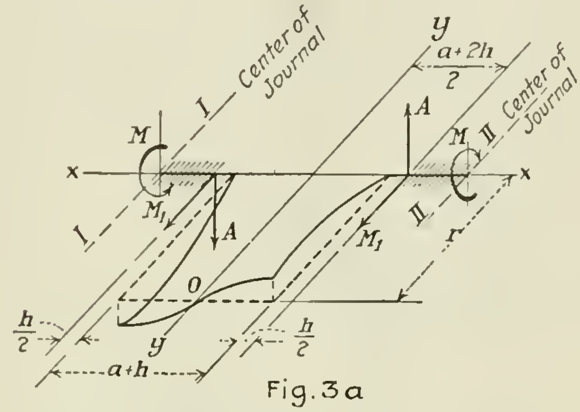
The deformed crank is shown diagrammatically in Figs. 3a and 3b. The constraint gives rise to a force A and a moment represented by the vector M_1 at each of the journals. The forces A and moments M_1 act in a plane through the axis of the journals perpendicular to the plane of the throw.

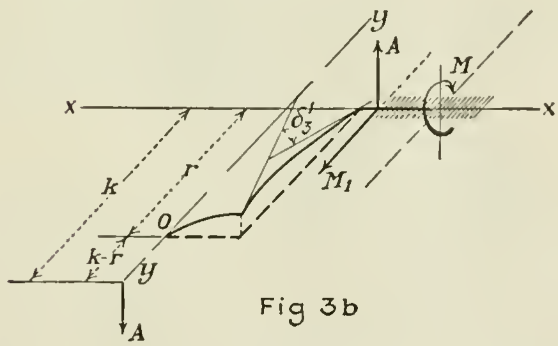
It is shown in the complete paper that—

$$l_0 = \left\{ \frac{2bC_0}{C_1} + a\left(1 - \frac{r}{k}\right)\frac{C_0}{C_2} + 2h\left(1 - \frac{r}{2k}\right)\frac{C_0}{C_3} + 2r\left(1 - \frac{r}{2k}\right)\frac{C_0}{B_3} \right\} \ldots\ldots\ldots [6]$$

from which it is seen that the reduced length of the throw is completely determined if we know the fraction r/k. For $A = 0$ or $k = \infty$ we must have the case of no constraint and, indeed, by placing $k = \infty$ in [6] we obtain [5]. The effect of the constraint is therefore measured by the quantity k. And in the special case where $2b = a$ and $C_1 = C_2$ we can immediately compare the case of a complete constraint with no restraint and find that the constraint decreases the reduced length in the ratio of 1 to $[1 - (r/2k)]$.

The author then proceeds to determine Equation [7], which makes it possible to calculate k, whence l_0 is obtained from [6]. γ is a coefficient having the value 1.2.





Figs. 3a and 3b Diagrammatic Representation of Deformed Crank—Case II

$$k = \frac{\frac{r(a+h)^2}{4C_3'} + \frac{ar^2}{2C_2} + \frac{a^3}{24B_2} + \frac{r^3}{3B_3} + \frac{hr^2}{4C_3} + \frac{\gamma a}{2F_2G} + \frac{\gamma r}{F_3'G} + \frac{\gamma h}{F_3G}}{\frac{ar}{2C_2} + \frac{r^2}{2B_3} + \frac{hr}{2C_3}} \quad [7]$$

This equation is at variance with the equation given by Geiger (Ueber Verdrehungsschwingungen von Wellen), for which reason, and as a check on the above results, the derivation of k and l by means of Castigliano's theorem is given in an appendix to the complete paper. This method is particularly useful in more complicated cases where the deformation of the throw is not as easily seen as in the preceding case.

Case III—Partial Constraint

It is here supposed that there is ample clearance in the halves of the bearings nearest the web, and no clearance in the other half. See Figs. 4a, 4b and 4c. In this manner we will now have bending, as well as torsion, in the halves of the journal next to the webs, a condition which no doubt prevails in practice. The author finds that—

$$k = \frac{\dfrac{r(a+h)^2}{4C_3'} + \dfrac{ar^2}{2C_2} + \dfrac{a^3}{24B_2} + \dfrac{r^3}{3B_3} + \dfrac{hr^2}{4C_3} + \dfrac{\gamma a}{2F_2G} + \dfrac{\gamma r}{F_3'G} + \dfrac{\gamma h}{F_3G}}{\dfrac{ar}{2C_2} + \dfrac{r^2}{2B_3} + \dfrac{hr}{2C_3}}$$

$$+ \frac{b^3}{3B_1} + \frac{b^2(a+2h)}{2B_1} + \frac{b(a+2h)^2}{4B_1} + \frac{\gamma b}{F_1G} \cdots \quad [8]$$

Numerical Example

Let $d_1 = d_2 = 10.25$ in.; $a = 13$ in.; $r = 11$ in.; $b = a/2 = 6.5$ in.; $h = 5.5$ in.; $c = 14$ in. Then—

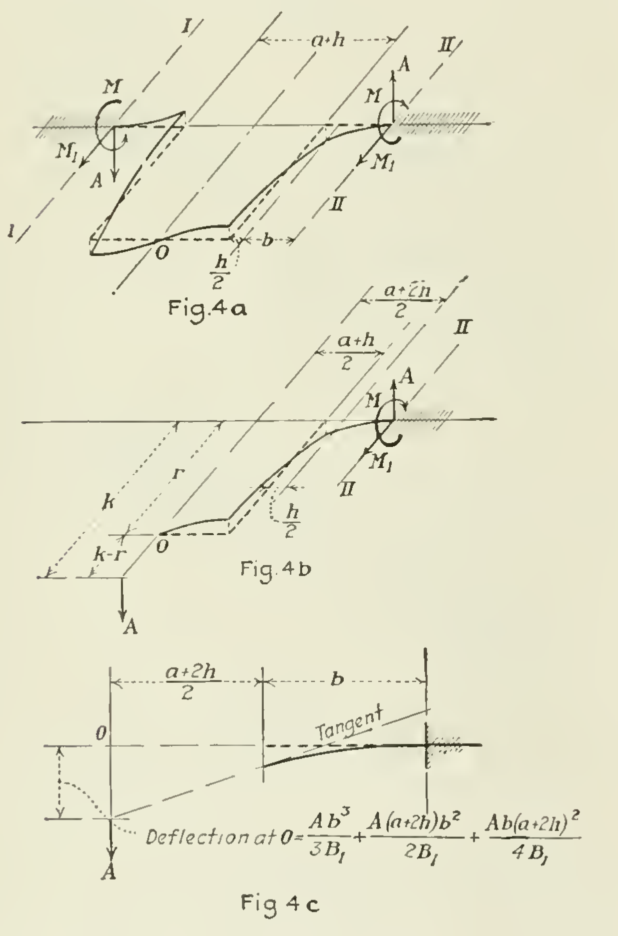
$$B_1 = B_2 = \frac{\pi \times 10.25^4 E}{64} = 54E;\ B_3 = \frac{5.5 \times 14^3 E}{12} = 1258E$$

$$C_1 = C_2 = \frac{\pi \times 10.25^4}{32} G = 1085G;$$

$$C_3' = \frac{14^3 \times 5.5^3}{3.6(14^2 + 5.5^2)} G = 562G$$

$$C_3 = \frac{14^3 \times 11^3}{3.6(14^2 + 11^2)} G = 3200\,G$$

Take $E/G = 2.6$ and the diameter of the equivalent shaft equal



Figs. 4a, 4b, 4c Diagrammatic Representation of Crankshaft—Case III

to the diameter of the journal, whence in this example $C_0 = C_1 = C_2$. Then, when there is no constraint (Case I), substitution in Equation [5] gives—

$$l_0 = 37 \text{ in.}$$

For the case of a complete constraint (Case II), Equation [7] gives—

$$k = 31.6 \text{ in.}$$

and since in the present case $2b = a$, the complete constraint reduces l_0 in the ratio—

$$1 : \left(1 - \frac{r}{2k}\right) = 1 : (1 - 0.174)$$

that is, the reduced length is reduced by 17.4 per cent.

In the case of a partial constraint (Case III), Equation [8] gives—

$$k = 44.2 \text{ in.}$$

and the reduced length, as compared with the case of no constraint, is reduced in the ratio of—

$$1 : \left(1 - \frac{11}{2 \times 44.2}\right)$$

that is, by 12.5 per cent.

These examples plainly show the effect of the constraint at the bearings. The more complete it is, the stiffer the shaft and the shorter the reduced length. The calculations further show that an increase in the diameters of journal and pin and an increase in the length of the pin cause an increase of k and thereby a reduction of the effect of the constraint and reduced bearing pressures A. On the other hand, an increase in the thickness of the web brings about a smaller length k and a corresponding augmentation of the bearing reactions.

Corrosion Problems

A paper on Corrosion as Affecting Metals Used in the Mechanical Arts was read on December 5, 1922, before the Sheffield Association of Metallurgists and Metallurgical Chemists, by Dr. W. H. Hatfield, Brown-Firth Research Laboratories, and past-president of the Association. The object of the paper was to give the particulars and results of an interesting set of experiments made at these laboratories to decide upon the resistance of typical industrial metals to various corroding agents. Dr. Hatfield referred to former work in the matter of various steel alloys, including that by Brearley in regard to stainless steel, and added that acid tests—the means generally employed—gave no direct indication, unfortunately, of the usefulness of an alloy for general corrosion-resisting purposes. A 30 per cent nickel steel was very resistant to sulphuric and hydrochloric acids, but was rapidly soluble in nitric acid of 1.20 specific gravity. The 14 per cent chromium steel was readily soluble in hydrochloric and sulphuric acids, but insoluble in nitric acid, while the 15 per cent silicon steel, although practically insoluble in all three acids, could not be considered completely rustless. These outstanding facts led largely to the carrying out of the experiments.

The materials dealt with numbered over twenty, and in addition to pure irons, carbon steels, alloy steels, cast-iron, they included nichrome and a good selection of non-ferrous metals.

He drew the two following conclusions: (1) There were now available steels and alloys which could effectively resist ordinary corroding influences. The different alloys, while at times each resisting the same media, did not give the same response to other media. It was essential in the application of corrosion- and acid-resisting alloys for actual practical experiments to be made in connection with the particular application intended, since not only composition, but also concentration, temperature, and extraneous influences had to be considered. (2) There was no obvious law, or set of laws, at present available, nor was any existing working theory sufficiently satisfactory to render effective aid to the investigator.

In regard to determining the relation which might exist between the electrode potential and solubility, it being understood that solubility was a function of electrode potential, the author said the main remarks to be put forward were: (1) When rapid solution took place the potential was highly negative; (2) when the potential had a high positive value very little corrosion or chemical action took place; and (3) otherwise the magnitude of the potential gave no indication of the solution properties of the metal. Another point worthy of note was the fact that in those cases in which rapid corrosion took place with evolution of gas, the potentials in hydrochloric and sulphuric acids were approximately the same, while in the case of the normal acids (acids containing 1 gram of available hydrogen per liter) the potential in nitric acid was about 0.2 volt less negative than in the other two acids. No satisfactory explanation of these observations could be put forward. The history of the metal would have some influence on the measured electrode potential, as shown by a table included in the paper. *Engineering*, Dec. 15, 1922, p. 747.

The Design of Cooling Towers

By C. S. Robinson,[1] Cambridge, Mass.

The author points out that engineers have designed cooling towers in the past on empirical information and in accordance with the experience of previous successful designs. Wide departure from standard designs is difficult because of the lack of scientific basis for the design. The author therefore establishes the general principle applicable to cooling-tower design and derives equations for the use of the designer. He presents a quantity of experimental data to substantiate the validity of his formulas and shows by an actual experiment how these formulas are applicable to the design of a counter-current cooling tower.

THE factors influencing the design of cooling towers have been studied by a number of investigators. There has been, however, no statement of the influence of these factors of such a nature that it has been possible to calculate easily the performance of a given tower under widely varying internal and external conditions. Engineers have found that towers of specified construction, when operated at specified air and water rates, may be expected to cool water to within a certain number of degrees of entering air tempeature and to discharge the air from the tower nearly saturated at some temperature approaching that of the entering water. In the absence of anything but empirical information, towers are therefore constructed along certain well-established and successful lines. However, this empirical knowledge will not enable the engineeer to predict what will happen when conditions depart widely from standard practice.

Investigations carried on by the Department of Chemical Engineering at the Massachusetts Institute of Technology under the direction of W. K. Lewis in connection with humidification and air drying, have led to the development of fundamental conceptions as to the mechanism involved in the transfer of heat between liquids and gases and in the vaporization and condensation of liquids and vapors. It is the purpose of this paper, which is based on the principles demonstrated in one written by Professor Lewis,[2] to show how these concepts can be applied to the particular case of cooling towers, and to devise by these means methods by which the engineer can simplify their design.

General Principles

There are two principles upon which all of the subsequent work will be based, (*a*) the conservation of matter and energy, and (*b*) the potential concept. The latter may be expressed briefly as the effect upon the rate of flow of matter or energy of the driving force applied.

The conservation of energy as applied to a cooling tower may best be shown by means of a heat balance. This can be written as—

$$s_w w(t_1 - t_0) = Ws'(T_1 - T_0) + Wr'(H_1 - H_0) \qquad [1]$$

where s_w = average specific heat of the water between the bottom and top of the tower

w = weight of water leaving tower

s' = humid heat[3] if the air entering the tower, that is, the heat required to raise one degree in temperature one pound of dry air plus the water vapor H that it contains

T = temperature of air

t = temperature of water

W = weight of air (moisture free) entering tower

r' = total heat of water vapor at the top of the tower at the temperature of the leaving air minus the heat of the liquid of water at the temperature of the entering water.

The subscripts 1 and 0 refer to the top and bottom of the tower, respectively.

Equation [1] is used universally by engineers at the present time in cooling-tower problems, usually in the approximate form—

$$w(t_1 - t) = Ws(T_1 - T_0) + Wr(H_1 - H_0) \qquad [2]$$

where s and r are the average humid heat and latent heat between the top and bottom of the tower, respectively.

The potential concept may be applied to both the rate of transfer of heat from the liquid to the gas and to the rate of diffusion of water vapor from the liquid to the gas, as shown in the following paragraphs.

The rate or flow of heat is proportional to the temperature difference between the liquid and the gas, and the rate of diffusion of water vapor is proportional to the difference between the vapor pressure of the liquid water and the partial pressure of the water vapor in the gas. The amount of heat flowing from the water to the gas per unit time would therefore be—

$$WsdT = haAdx(T - t) \qquad [3]$$

where h is the coefficient of heat transfer per unit area (sq. ft.), a the square feet of cooling surface per cubic foot of volume of the tower, A the cross-sectional area of the tower, and x the height of the tower.

In the same way the weight of the vapor vaporizing per unit time would be—

$$wdH = k'aAdx(P' - p) \qquad [4]$$

where k' is the diffusion coefficient in pounds per unit area of exposed surface, P' the vapor pressure of the water, and p the partial pressure of the water vapor in the air. Since for small partial pressures p is nearly proportional to the absolute humidity H, Equation [4] may be written as—

$$WdH = kaAdx(P - H) \qquad [5]$$

where P, the vapor pressure of the water, is expressed in terms of absolute humidity, that is, the absolute humidity of saturated air at the temperature of the water in question.

Dividing [5] by [3] gives—

$$\frac{dH}{sdT} = \frac{k(P - H)}{h(T - t)} \qquad [6]$$

The mechanism by which the heat passes from water to the air may be understood by considering that the heat flows first from the interior of the water to the surface, and then from the surface through a substantially stationary air film in contact with the surface to the moving air.

It has been shown[2] that $h/k = s$ when h refers to the coefficient of heat transfer through the air film only. If the total coefficient of heat transfer from the interior of the water to the moving air be used instead of h, the ratio h/k would not equal s, but would only approximate it to a greater or lesser degree according to whether the heat flow through the water took place easily or with difficulty as compared with the flow through the air film.

Unless otherwise noted h and k will henceforth refer to the overall coefficient of heat transfer and vapor diffusion, respectively.

Therefore, taking $h/k = s$, [6] becomes—

$$\frac{dH}{dT} = \frac{P - H}{T - t} \qquad [7]$$

Equation [7], stated in words, says that the *differential* increase in humidity of the air is to the *differential* increase in temperature of the air as the humidity difference between the air and the water is to the temperature difference between the air and the water.

Equation [7] when integrated between proper limits would give the change in humidity and temperature of the water in its passage through the cooling tower. However, while the humidity of the air and the vapor pressure of the water are related to each other and the temperatures of the air and water are also related, the relationships are nevertheless of such a nature that exact integration is impossible, and an approximation is obtained by the following assumption.

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[1] Department of Chemical Engineering, Massachusetts Institute of Technology.

[2] W. K. Lewis, The Evaporation of a Liquid into a Gas, Mechanical Engineering, July, 1922, p. 445.

[3] Wm. S. Grosvenor, Trans. Am. Inst. Chem. Engrs., 1908.

Presented at the Annual Meeting, Dec. 4 to 7, 1922, of The American Society of Mechanical Engineers. Slightly abridged. All papers are subject to revision.

It will be noted that the temperature difference between the water and the air in a counter-current cooling tower does not change greatly between the top and bottom of the tower, nor does the difference in humidities between the water and air. It is therefore a justifiable assumption that the average temperature difference is approximately equal to the arithmetical mean temperature difference, and that the average humidity difference is approximately equal to the arithmetical mean humidity difference. It may therefore be said that for the whole tower the total increase in humidity of the air is to the total increase in temperature of the air as the arithmetical mean humidity difference between the air and the water is to the arithmetical mean temperature difference between the air and the water.

For the tower shown in Fig. 1 where the subscripts 0 and 1 represent conditions at the bottom and top, respectively, there may now be written—

$$\frac{H_1 - H_0}{T_1 - T_0} = \frac{H_1 - P_1 + H_0 - P_0}{T_1 - t_1 + T_0 - t_0} \qquad \text{[8]}$$

which is the integrated form of Equation [7].

Experimental Data

The author has collected and arranged in Table 1 the results of twenty-three tests made by himself and others on various types of cooling towers.

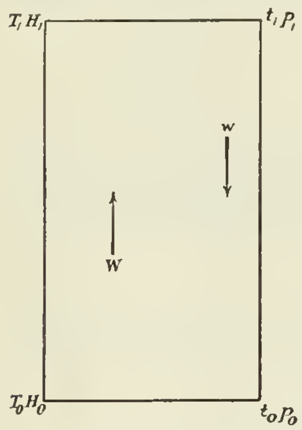


FIG. 1 DIAGRAMMATIC REPRESENTATION OF COUNTER-CURRENT COOLING TOWER

Tests 1 to 5 were on a slat type of forced-draft tower, 6 and 7 were on the same tower operating under natural draft, and Test 23 was on a Wheeler-Balke tower, all described in the Journal of the Ohio Society of Mechanical, Electrical and Steam Engineers, vol. 7. Tests 8 and 9 were on a forced-draft slat-type tower described in the Journal of the American Society of Refrigerating Engineers, vol. 3, 1916–17, p. 32. Test 10 was on a natural-draft tower described in the Transactions of The American Society of Mechanical Engineers, vol. 31, 1909, p. 75. Tests 11 to 22 were on an experimental Badger spray-type tower erected at the Massachusetts Institute of Technology, and the results have not been previously published.

The method of calculating the data may be explained by reference to Test 1.

T_0, (T_1) = temperature of inlet (outlet) air, deg. fahr.
t_1, (t_0) = temperature of inlet (outlet) water, deg. fahr.
Rel. Hum. = relative humidity in per cent
Q = heat given up by water in B.t.u. per min.
$= 651 \times 8.3 \times (105 - 84.7) = 110{,}500$
V = cubic feet of air per minute
H_0 = absolute humidity of inlet air in pounds of water per pound of dry air, as read from humidity chart[1]
P_0 = equivalent absolute humidity of outlet water, i.e., the absolute humidity of air saturated at the water temperature
H_1 = absolute humidity of outlet air, assuming saturation
P_1 = equivalent absolute humidity of inlet water
H = mean humidity difference between the air and water
$$= \frac{0.026 - 0.006 + 0.050 - 0.031}{2} = 0.0195$$
W = pounds of dry air per minute, as calculated from the volume of air V divided by the bumid volume (the cubic feet occupied by one pound of dry air plus the water vapor which it contains, as read from the humidity chart)
w = pounds of water evaporated per minute
$= W(H_1 - H_0) = 3700(0.031 - 0.006) = 93$
$ka \times$ vol. = pounds of water evaporated in the whole tower per minute per one pound mean humidity difference
$$= \frac{93}{0.0195} = 4800$$
Q_{sens} = sensible heat picked up by the air per minute
$= Ws(T_1 - T_0)$, where s is the humid heat as read from the humidity chart[3] ($s = 0.25$)
$= 3700 \times 0.25(90 - 71) = 18{,}000$ B.t.u.
t = mean temperature difference between air and water
$= (105 - 90 + 84.7 - 71)/2 = 14.4$
$ha \times$ vol. = B.t.u. picked up as sensible heat by air in the whole tower per degree temperature difference
$$= \frac{18{,}000}{14.4} = 1250$$
$$\frac{h}{k} = \frac{ha \times \text{vol.}}{ka \times \text{vol.}} = \frac{1250}{4800} = 0.26$$
$$ha = \frac{ha \times \text{vol.}}{\text{vol.}} \text{ where "vol." is the volume of the tower.}$$

The dimensions of the tower in Test 1 were not given in the article, but other information led to the assumption that the tower was 10 × 10 × 22 ft., a volume of 2200 cu. ft., whence—

$$ha = \frac{1250}{2200} = 0.57 \text{ and } ka = \frac{4800}{2200} = 2.18$$

[1] Wm. S. Grosvenor, Trans. Am. Inst. Chem. Engrs., 1908.

TABLE 1 COOLING-TOWER TEST DATA

Test No.	Tower No.	T	T_1	t_1	t_0	Rel. hum.	Gal. per min.	Q	V
1	1	71	90	105	84.7	40	651	110,500	53,900
2	1	72	93	107.8	87.5	60	638	108,000	50,100
3	1	64	96	112	88.5	60	638	124,500	51,400
4	1	69	92	108.5	87	48	643	115,000	52,200
5	1	83	95	109.9	90.5	48	640	103,400	50,600
6	1	43	101	116	98	75	632	94,800	23,500
7	1	60	118	135	115.8	73	630	102,000	15,575
8	2	82	99	115	83	65	617[c]	176,800	72,700
9	2	75	96	109	81	74	668	168,800	72,700
10	3	25	80[a]	87.5	71.3	72	590	78,000	......
11	4	75.8	87.7	95.1	89.1	85	248	12,400	11,100[c]
12	4	77.0	103.9	112.1	99.2	78	230	24,700	9,060[c]
13	4	79.0	112.1	123.3	105.5	76	219	32,400	8,490[c]
14	4	76.1	89.9	94.4	87.9	60	288	15,500	9,700[c]
15	4	76.9	101.7	106.5	95.5	60	278	25,400	8,930[c]
16	4	77.0	112.9	123.7	105.2	57	259	39,800	8,970[c]
17	4	72.1	91.2	94.5	88.0	78	254	13,700	8,090[c]
18	4	73.0	105.1	113.7	99.9	75	246	28,100	9,030[c]
19	4	76.6	115.0	132.1	109.4	68	237	44,700	9,590[c]
20	4	72.9	90.9	92.4	88.4	87	269	8,900	6,160[c]
21	4	72.3	105.4	113.3	100.6	89	257	27,000	8,870[c]
22	4	72.7	115.2	128.2	108.1	88	241	40,200	8,800[c]
23	5	91	106	109	97	59	3,200	319,000	125,000[c]

Test No.	Tower No.	H_0	P_0	H_1	P_1	H	W	Δw	$ka \times$ vol.
1	1	0.006	0.026	0.031	0.050	0.0195	3700	93	4,800
2	1	0.010	0.028	0.034	0.055	0.0195	3410	82	4,200
3	1	0.008	0.029	0.037	0.062	0.023	3460	100	4,300
4	1	0.007	0.028	0.033	0.056	0.022	3560	89	4,000
5	1	0.012	0.031	0.036	0.058	0.0205	3420	82	4,000
6	1	0.004	0.040	0.044	0.071	0.0315	1550	62	2,000
7	1	0.008	0.070	0.075	0.129	0.057	915	61	1,100
8	2	0.015	0.024	0.041	0.068	0.018	5200[c]	135	7,500
9	2	0.014	0.023	0.037	0.057	0.0145	5276[c]	121	8,300
10	3	0.002	0.016	0.022	0.028	0.010	5200[c]	99.5	.....
11	4	0.015	0.030	0.027	0.036	0.012	790[c]	9.5	790
12	4	0.015	0.041	0.045	0.063	0.022	648[c]	19.4	880
13	4	0.016	0.051	0.059	0.090	0.033	606[c]	26.7	810
14	4	0.011	0.029	0.029	0.035	0.012	693[c]	12.5	1,040
15	4	0.011	0.037	0.043	0.052	0.018	638[c]	20.4	1,130
16	4	0.011	0.050	0.061	0.090	0.034	641[c]	32.0	940
17	4	0.013	0.029	0.031	0.036	0.0105	578[c]	10.4	990
18	4	0.013	0.042	0.047	0.066	0.024	644[c]	21.9	910
19	4	0.013	0.058	0.065	0.118	0.049	692[c]	36.0	730
20	4	0.015	0.029	0.030	0.033	0.0085	440[c]	6.6	780
21	4	0.015	0.043	0.048	0.065	0.023	633[c]	20.9	910
22	4	0.015	0.055	0.066	0.104	0.039	628[c]	32.0	820
23	5	0.019	0.039	0.051	0.057	0.013	8250[c]	273.0	21,000

Test No.	Tower No.	Q_{sens}	Δt	$ha \times$ vol.	h/k	ha	ka	u	$100 \times \frac{ka}{u}$
1	1	18,000	14.4	1250	0.26	0.57	2.18	540	0.40
2	1	21,000	15.2	1380	0.33	0.63	1.91	500	0.38
3	1	32,000	20.3	1570	0.36	0.71	1.96	510	0.38
4	1	24,000	17.3	1390	0.35	0.63	1.82	520	0.35
5	1	12,000	10.7	1120	0.28	0.51	1.82	510	0.36
6	1	26,000	35	740	0.37	0.34	0.91	240	0.38
7	1	15,000	36.4	410	0.37	0.19	0.50	160	0.31
8	2	23,000	24.5	1470	0.20	0.46	2.36	320	0.77
9	2	29,000	25	1720	0.21	0.54	2.61	320	0.82
10	3	......	....	....	....	....	....	...	....
11	4	2,400	10.4	230	0.29	0.17	0.57	174	0.33
12	4	4,300	15.2	283	0.32	0.20	0.64	142	0.45
13	4	4,400	18.9	233	0.29	0.17	0.59	133	0.44
14	4	2,400	8.2	292	0.28	0.21	0.75	151	0.50
15	4	4,000	11.7	342	0.30	0.25	0.82	140	0.58
16	4	6,200	19.5	318	0.34	0.23	0.68	140	0.49
17	4	2,800	9.6	292	0.30	0.21	0.72	126	0.57
18	4	5,100	18.9	270	0.30	0.21	0.66	141	0.47
19	4	6,900	25.0	276	0.38	0.20	0.53	150	0.35
20	4	2,000	8.4	238	0.31	0.17	0.57	96	0.59
21	4	5,000	18.1	276	0.30	0.20	0.66	139	0.47
22	4	6,600	24.2	273	0.33	0.20	0.59	125	0.47
23	5	31,000	4.5	7,000	0.33	....	....	...	....

[a] Assumed values. [c] Calculated values.

u = linear velocity of air through the total cross-section of the tower

$$= \frac{53{,}900}{10 \times 10} = 540 \text{ ft. per. min.}$$

$$\frac{ka}{u} = \frac{2.18}{540} = 0.0040$$

The most interesting tests are those numbered 1 to 7, which have been quoted several times in articles by different investigators. In these tests the first five were under forced draft, while the last two were under natural draft, with much reduced air velocity. A plot of ka versus air velocity for these seven tests gives a straight line passing through the origin.

It has been noticed by others[1] that the rate of cooling in towers is approximately proportional to the air velocity. Investigations at the Institute being carried on at the present time indicate that ka for humidifying apparatus in general is probably proportional to a power function of the air velocity something less than one, but for the present, at least, linear proportionality is a fairly close approximation. While k is the actual coefficient of diffusion per square foot of surface, since in many types of towers the active surface cannot be accurately measured the coefficient ka is used instead, where a represents the actual surface in square feet per cubic foot of tower. In most towers a is uniform throughout the volume of the tower.

It is therefore justifiable to call the value ka/u the "tower constant" and to use the value of this constant as a means for comparing the operation of towers of various sizes and types. Thus for tower No. 1 the average value of ka/u is 0.0037 and the average deviation from this value is 0.00021, or less than 6 per cent, while the maximum deviation is 0.0006, or 16 per cent. The important thing indicated by these tests is that ka/u was unaffected whether the tower was operated with forced or with natural draft.

Tower No. 4 has an average value of 0.00475 for ka/u, with an average deviation of 10 and a maximum deviation of 31 per cent.

Tower No. 2 has an average constant of 0.0080, which is high compared with the other towers tested. The drop in pressure through this tower was not published. It would be interesting to compare its drop in pressure with that in other towers which show smaller tower constants. It is of course obvious that a high tower constant can be obtained by obstructing the flow of air through the tower by cutting down the mean free area, but this again is at the expense of friction and back pressure. Wherever possible the drop in pressure through the tower should be measured and published.

The average value of the humid heat of air in a cooling tower is about 0.25. It will be noted that the column h/k in Table 1, which should be approximately equal[2] to s, has values of the same order of magnitude in general, but which are somewhat higher. The reason for this as predicted from the statements made in Par. 12 is shown by the fact that, while the surface of the water is at a lower temperature than the interior, making the true h for the air film greater, the value of k was calculated for the average water temperature instead of using the surface temperature. The latter is lower and would give a higher value for k. But since the vapor pressure of water rises more rapidly than the temperature, the ratio of h to k calculated on the average water temperature would be greater than that calculated on the lower surface temperature, which was the case in all but two cases in Table 1. The experimental data are therefore offered as proof of the validity of Equation [7].

Information regarding the size of tower in Test 23 was not available. It would be interesting to compare the values of ha and ka for this large tower with those of the smaller ones in the previous tests.

The results of the calculations of the test runs are felt to confirm in a remarkable manner the conceptions regarding humidification in general as developed by W. K. Lewis, furnishing as they do ample experimental proof of their validity.

Application of Equations Developed to Tower Design

The value of the foregoing equations with respect to cooling-tower design may best be shown by means of an example.

In any cooling tower the law of conservation of energy must apply. This law is represented by the heat balance of Equation [1]. Furthermore, in any cooling tower there is a necessary relationship between the amount of heat transferred by conduction and that eliminated by evaporation which is represented by Equation [8]. Finally, the capacity of any cooling tower is determined by the rate of transfer of heat and the rate of diffusion of vapor in it. These rates are dependent upon the design of the tower, and can only be determined on the basis of experimental data on the performance of towers of the type in question. The capacity factor is covered by Equation [3] or Equation [5] in the differential, but in actual design it is more satisfactory to use an integrated form of Equation [5] obtained by the use of arithmetical mean humidity differences and represented by Equation [9]. The combination of these three equations represents the conditions that must obtain in any tower and therefore serve as a proper basis for tower design.

The coefficient ka/u expresses the volumetric capacity of any particular type of tower. Experimental determination of this constant is necessary before design can be accomplished.

It is necessary for the engineer to select the type of tower most suitable for his purpose, and, from previous tests on towers of similar type, obtain values of ka which can be anticipated. In general certain specifications must be met. There may be:

Weight of water to be cooled, w (= 3000 gal. per min.)
Temperature of water to be cooled, t_1 (= 110 deg. fahr.)
Temperature to which water must be cooled, t_0 (= 80 deg. fahr.)
Average (or worst) outside air temperature, T_0 (= 80 deg. fahr.)
Average (or worst) outside air humidity, H_0 (= 0.0130, i.e., 60 per cent relative humidity)

for which the values in parentheses may be taken, those for T_0 and H_0 being the worst atmospheric conditions under which a tower must cool the water at 80 deg. fahr.

It will be noted that the condition of reducing the temperature of the water to that of the entering air is exceptionally severe and will call for a tower considerably larger than usual, since towers rarely have to meet such specifications.

There are in this case three unknown conditions, the temperature and humidity of the outgoing air, and either the volume of the tower or the ratio of the amount of air to the amount of water. The air-water ratio is usually determined by the type of tower selected and is therefore known, leaving the volume of the tower as the third unknown.

In order to calculate these unknown quantities three independent equations are needed. These may be taken as Equations [2], [8] and [9], and an integrated form of Equation [4] obtained by employing the same assumption as that used in integrating Equation [7], namely,

$$W(H_1 - H_0) = kaAx\,\frac{P_1 + P_0 - H_1 - H_0}{2} \quad\ldots\ldots\ldots[9]$$

Equations [2], [8], and [9] may be solved simultaneously for H_1, T_1, and Ax (which latter equals the volume of the tower). The author has seen fit to solve for W instead of Ax, but after H_1 and T_1 have been found it is easy to convert the solution for W into that for Ax.

$$W = -\frac{\dfrac{w(t_1 - t_0)}{s(2T_0 - t_1 - t_0) + r(2H_0 - P_1 - P_0)}}{1 + \dfrac{2w(t_1 - t_0)}{kaAxs(2T_0 - t_1 - t_0) + r(2H_0 - P_1 - P_0)}} \quad\ldots[10]$$

In the particular problem in question, suppose that a forced-draft slat-type tower such as was used in Tests 1 to 7, whose tower constant ka/u is 0.0037, be selected. Towers of this type are found to be economical when handling 6.5 gal. of water per min. per sq. ft. of ground area with an air velocity of about 500 ft. per min.

The area of the proposed tower will therefore be 3000/6.5 = 460 sq. ft., and the volume of air will be 500 × 460 = 230,000 cu. ft. per min. The humid volume of one pound of dry air as read from the humidity chart is 13.8 cu. ft. Therefore—

$$W = \frac{230{,}000}{13.8} = 16{,}700 \text{ lb. per min.}$$

also—

$w = 3000 \times 8.3 = 25{,}000$	$r = 1050$ (approx.)
$t_1 = 100$	$H_0 = 0.013$
$t_0 = 80$	$P_1 = 0.0585$
$s = 0.24$	$P_0 = 0.022$
$T_0 = 80$	$ka = 0.0037 \times 500 = 1.85$

[1] Jour. Am Soc. Refrig. Engrs., vol. 3. 1916–17, p. 32.
[2] W. K. Lewis, The Evaporation of a Liquid into a Gas, Mechanical Engineering, July, 1922, p. 445.

Substituting these values in Equation [10] and solving for Ax gives 41,500 cu. ft. for the volume of the tower, and since the ground area was determined to be 460 sq. ft., the tower height would be 41,500/460 = 90 ft. The severe conditions imposed account for the great height required.

If the tower be built as calculated, the performance under any other atmospheric conditions may be readily calculated by substitution in the proper equation.

The author realizes that the foregoing methods of calculating cooling-tower performance do not form the complete solution of the problem, and that the ultimate design of the best tower will depend upon the striking of an economic balance between the size of the tower and the cost of moving the water and the air. He feels, however, that this method of calculation is distinctly in advance of anything which has thus far appeared in print, that it furnishes a convenient and accurate tool for the designing engineer, and that it is the necessary basis for the economic balance referred to.

Finally, the author wishes to urge the inclusion of more complete and more accurate data in published accounts of tower performances. Of all the published tests studied, only those tabulated had sufficient data to enable them to be analyzed, and even then, in most cases, assumptions were necessary. Inaccurate data are often common. Test No. 10 is an example of this, the heat of vaporization alone being considerably greater than the total cooling of the water, which inaccuracy renders the test useless for purposes of analysis. A more complete knowledge of the effect of varying conditions on ha and ka can only come from studies of large numbers of accurate tests, and it is upon such increased knowledge that advance in tower design depends.

Discussion

B. H. Coffey[1] wrote that the members of the American Society of Refrigerating Engineers present at the session would remember that Mr. George Horn and he had devoted much time and study to this subject. They were therefore gratified to see the theory of cooling towers becoming of interest to the scientific men of college faculties as instanced by Mr. Robinson's paper. If the unequaled experimental facilities and mathematical ability of our great engineering schools became engaged upon this subject, they believed it could be shortly put upon a practical basis for the general profession.

All cooling towers, Mr. Coffey wrote, were more structural assemblages of cooling surface, the cost of which was by far the largest item in the installation. For this reason the designer and purchaser were peculiarly interested in the area of surface required to do the specified cooling. The discussion would therefore be confined to the points bearing on this part of the subject.

Equations [3] and [4] showed the dual heat currents that always existed between air and water when not in thermal equilibrium, both expressions containing a cooling surface term and transmission coefficient. In Equation [3] the potential or driving force was temperature difference and in Equation [4] pressure difference. For future reference they—Mr. Coffey and Mr. Horn—wished to point out that by simple transposition in each equation the surface increment would equal the heat increment multiplied by the reciprocal of the potential and consequently for zero potential the surface increment was infinite.

By ingenious use of the connecting constant s, Equation [7] was established showing the relation between the latent and sensible heat currents. The author failed to integrate this equation, however, and resorted to an approximation with which they took issue.

This approximation was based upon the assumption that the mean of the extreme differences was the true mean and the assumption was based upon the stated fact that in counter-current cooling towers the pressure and temperature differences did not change greatly between the top and bottom of the tower. No evidence was offered to support this statement, which they disputed. Referring to Table 1, tests 1 to 7, the temperature differences at the bottom of tower as a percentage of those at the top ranged from 91 to 366 per cent, and on the same basis the pressure differences varied from 83 to 148 per cent. These figures were sufficient to cast grave doubts upon the author's statement and basis of his approximation and that probably the mean potentials he obtained were not the true means.

[1] Elizabeth, N. J. Mem. Am.Soc.M.E.

If the mean potentials were incorrect the mean transmission coefficients h and k which were derived from them were incorrect and the ratio h/k would be incorrect. Referring to Table 1, col. h/k, they found this ratio varied from 0.20 to 0.38 when it should be approximately constant and about 0.25. The explanation of these wide discrepancies given by the author was not convincing to them.

The extraordinary height of tower, 90 ft., to meet the not particularly severe conditions as obtained from the simultaneous Equation [10], was they believed, due to incorrect mean potentials.

As a further test of Equation [10] they had used for final water temperature 69.7 deg. the wet-bulb temperature of the entering air. Under these conditions the total potential became zero and the cooling surface infinity, as pointed out above. The calculation resulted in a tower 230 ft. high instead of infinity, which they again would attribute to incorrect mean potentials.

In their opinion this line of attack upon the cooling-tower problem, while promising, had failed to produce working formulas that expressed the cooling process. They suggested as a basis using total potential equations. The relation $h/k = s$ gave a means of converting temperature potential into equivalent pressure potential or the reverse. The total potential could be thus expressed either in temperature or pressure alone and the problem much simplified.

They noted with regret the absence of any reference to the wet-bulb temperature in the paper, a physical quantity universally regarded of the greatest importance in this subject.

W. M. Grosvenor[1] wrote that it was a real satisfaction to find after fourteen years that a piece of one's own work stood the test of time and was still of use to other engineers, particularly in such a very admirable consideration of cooling towers as the author had given in his paper. The article on Calculations for Drier Design to which he referred had been published in the *Proceedings* of the American Institute of Chemical Engineers and the *Heating and Ventilating Magazine* for 1908, when the best available data on humidity were those of the U. S. Weather Bureau, and on these figures the calculations were based and the resulting curves plotted. The conception was there introduced of representing what might be called adiabatic evaporative cooling by lines intersecting the curves of relative humidity on a chart having temperatures as one ordinate and weight of moisture per lb. of air, volume per lb., B.t.u. per lb. of air when damp (humid heat), etc., on the other ordinate. This had proved to be a very useful and easy way of calculation. Some three years later at the annual meeting of The American Society of Mechanical Engineers for 1911, in a paper entitled Rational Psychrometric Formulae, Willis H. Carrier had used this method of presenting a newly calculated set of curves based, Mr. Grosvenor believed, on more accurate data than those of the Weather Bureau. It seemed to him that Mr. Carrier had done a very excellent and valuable piece of research work that was very thoroughly discussed at that meeting but had received too little attention since. This valuable paper contained no reference to any previous publication of humidity charts with adiabatic cooling lines, etc., but Mr. Grosvenor desired to call the author's attention to it and to ask for it the careful consideration he believed it deserved.

Now that we had in the author's work the foundation laid for a more logical and clear understanding of the data needed for perfecting the design of cooling towers, it became the obvious duty of engineers having cooling towers under operation to determine as well as they could the conditions of operation and communicate the information to him. He would then be in a position to suggest changes in operating conditions if not in design and on the basis of the results before and after could revise and perfect what should be a very valuable solution of a problem that was becoming increasingly important with municipal growth.

L. A. Phillips[2] asked if the author's formula for cooling towers which, in the example in the paper had resulted in a tower 90 ft. high, had been checked with a tower of commercial height, say, about 30 ft.

[1] Cons. Chemist and Factory Engr., New York, N. Y.

[2] New York, N. Y.

Size Selection of Dry-Vacuum Pumps

By EDWARD W. NOYES[1] and HAROLD V. STURTEVANT,[1] CLAREMONT, N. H.

In pumping from atmospheric pressure down to a given vacuum with a dry vacuum pump, as during the process of exhausting a closed tank, the volumetric efficiency of the pump varies from that at atmospheric pressure to that corresponding to the given vacuum and an average value has to be determined to use in the theoretical formulas which apply to this kind of service.

Two methods of determining the average volumetric efficiency were successively tried out by the authors and results plotted in the form of curves, but these results did not check satisfactorily with those obtained in actual tests of an installation. The process of calculation employed in the second (and somewhat more accurate) method was then reversed, and working with actual test data, values were obtained from which a "constant" curve was plotted, this curve giving closely accurate results from 80 per cent perfect vacuum up. With the aid of this "constant" curve two charts have been plotted, by means of which it is possible to determine rapidly and with sufficient accuracy (1) the size of pump required to exhaust a given volume to a specified degree of vacuum in a predetermined time; or (2), where a vacuum pump is already installed, the time required to exhaust a given volume to a specified degree of vacuum.

DRY-VACUUM PUMPS are subjected to two different kinds of service, one of which may be classified as continuous vacuum service, in which the intake and delivery pressures remain practically constant during the operation of the pump; and the other as variable vacuum service, in which the intake pressure varies from atmosphere down to some low vacuum during the operation of the pump, as would be the case in exhausting a closed tank.

The dry-vacuum pump is employed on the latter class of work in many of the industries, notably in (1) creosoting and impregnation of wood; (2) dehydrating of food products; (3) in textile and dye works to assist in the penetration of the fabrics with dyes; (4) in electrical establishments, to remove air from insulation; and (5) in the extraction of wax from waste wax paper.

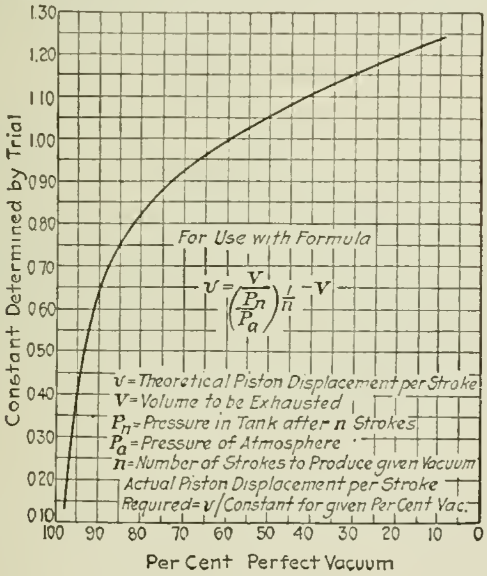


Fig. 1 Vacuum-Pump Constant for Use with General Formula for Piston Displacement

The problem of determining the size of vacuum pump required to evacuate a tank of given size to a certain degree of vacuum in a predetermined time seems to be a rather elusive one, and the purpose of this paper is to present a method for its solution which will apply to any set of conditions, and which may be quickly used to determine the correct size of pump, with accuracy sufficient for all practical purposes.

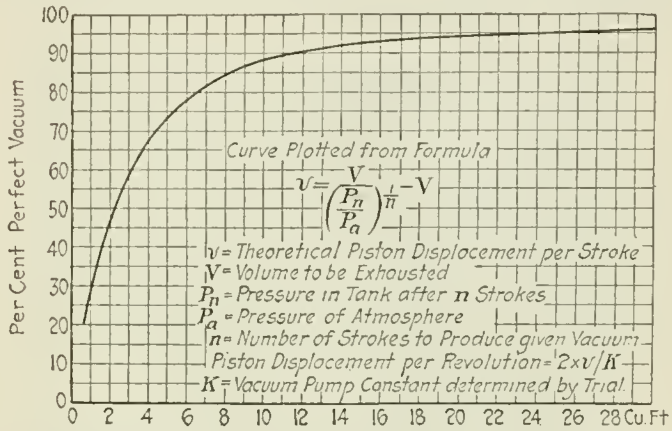
[1] Sales Engineer, Sullivan Machinery Company of Claremont, N. H., and Chicago, Ill.

Presented at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. Abridged. All papers are subject to revision.

The experimental work described was conducted at the Claremont N. H., plant of the Sullivan Machinery Company, and the machines used were the standard, straight-line, belt-driven vacuum pumps manufactured by that company.

Two methods of determining the average volumetric efficiency were successively tried out by the authors and the results plotted in the form of curves, but these results did not check satisfactorily with those obtained in actual tests of an installation. The process of calculation employed in the second (and somewhat more accurate) method was then reversed, and, working with actual test data, values were obtained form which a "constant" curve was plotted.

Fig. 1 shows this constant curve plotted against percentage of perfect vacuum. The individual constant curves of which it is an average show some divergence between zero and 80 per cent perfect vacuum, so that within this range the results obtained by using the chart are slightly inaccurate. From 80 per cent up, however, the values given are accurate for all practical purposes.



Piston Displacement per Revolution required to Exhaust a Volume of 1000 Cu. Ft. from Atmospheric Pressure to any Per Cent Vacuum with 300 Revolutions. (For a Different Volume or Number of Revolutions the Piston Displacement varies Directly as the Volumes and Inversely as the Revolutions.)

Fig. 2 Dry-Vacuum Pump Piston Displacement Required to Exhaust a Closed Space

It is evident that this curve is to be used in connection with the general formulas for solving any vacuum-pump problem rather than the average volumetric-efficiency curve, because the former has been determined from the results of tests on an actual installation.

In the general formulas given respectively in Figs. 2 and 3 there exist direct and inverse relationships between the variables which may be taken advantage of in plotting the curves. For example, in the formula of Fig. 2 v varies approximately inversely as n and directly as V, and in the formula of Fig. 3 n varies approximately directly as V and inversely as v.

This relationship makes it possible to plot the formula of Fig. 2 for some given values of V and n, such as $V = 1000$ and $n = 600$, and with v and the percentage of perfect vacuum as the variables. Then for any given case where the values of V and n are different from those in the plot, the value of v required would be directly proportional to V and inversely proportional to n. Likewise the formula of Fig. 3 can be plotted for some given values of V and v, such as $V = 100$ and $v = 0.5$, and with n and the percentage of perfect vacuum as the variables. Then for any given case the value of n required would be directly proportional to V and inversely proportional to v.

The value of v thus obtained was multiplied by 2 and divided by the constant determined by trial and plotted as piston displacement per revolution in Fig. 2. The value of n was divided by 2 and by the constant and plotted in Fig. 3 as total revolutions required.

Fig. 3 will apply to cases where the displacement of the pump is assumed or known and it is desired to find the total number of revo-

lutions required to exhaust a given volume to a predetermined vacuum. Knowing the time which may be used in the process, the r.p.m. of the pump may be obtained. A barometric pressure of 29.5 in. was used in the computations and the results plotted against percentage of perfect vacuum, so that the curve will apply with any barometric pressure. In using the curves, the average barometric pressure over a long period of time in any given locality should be used. Knowing the degree of vacuum desired, the percentage of perfect vacuum can be readily calculated. Following is a sample calculation used in the determination of this curve.

Barometer = 29.5 in.; vacuum in inches of mercury = 24; percentage of perfect vacuum = (24/29.5) × 100 = 81.3; V = 100 cu. ft.; v = 0.5 cu. ft. Then—

$P_n = (29.5 - 24) \times 0.4912 = 2.70$ lb. per sq. in.

$P_a = 29.5 \times 0.4912 = 14.49$ lb. per sq. in.

Also, from Fig. 1,

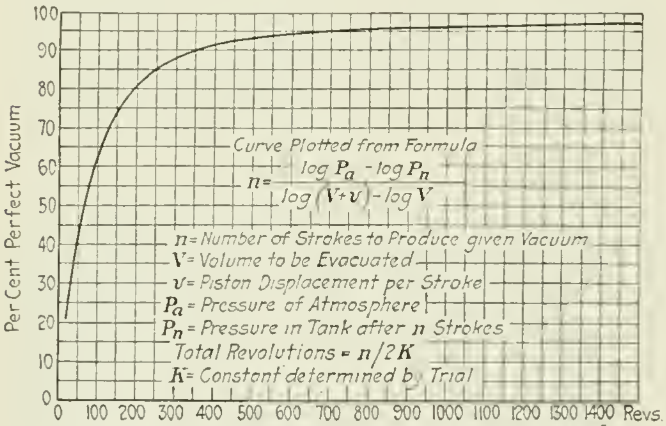
$K = 0.81$

Whence—

$$\text{Total revolutions} = \left(\frac{1}{2} \times \frac{\log 14.49 - \log 2.70}{\log (100 + 0.5) - \log 100}\right) \div 0.81 = 207.95.$$

Hence at 81.3 per cent perfect vacuum is plotted 207.95 revolutions. This same process was followed for about twenty different points and the curve thus obtained.

Fig. 2 will apply to problems in which the total revolutions or



Total Revolutions required to Exhaust a Space of 100 Cubic Feet from Atmospheric Pressure to any Per Cent Vacuum with a Pump of One Cubic Foot Piston Displacement per Revolution (For Different Volume or Piston Displacement the Total Revolutions vary Directly as the Volumes and Inversely as the Piston Displacement.)

Fig. 3 Dry-Vacuum Pump Revolutions Required to Exhaust a Closed Space

r.p.m. and time are known or assumed, and it is desired to calculate the piston displacement necessary to exhaust a given volume to a predetermined vacuum. A sample calculation used in the determination of this curve follows.

Barometer = 29.5 in.; vacuum in inches of mercury = 25; percentage of perfect vacuum = (25/29.5) × 100 = 84.7; V = 1000 cu. ft. Then—

$P_n = (29.5 - 25) = 4.5$ in. $\qquad P_a = 29.5$ in.

$n = 600$

$$v = \frac{V}{\left(\frac{P_n}{P_a}\right)^{1/n}} - V = \frac{1000}{\left(\frac{4.5}{29.50}\right)^{1/0.0016667}} - 1000 = 3.138$$

Actual piston displacement per revolution = 3.138 × 2/0.76 = 8.258 cu. ft., where 0.76 is the value of K from Fig. 1 for 84.7 per cent perfect vacuum.

Thus piston displacement of 8.258 cu. ft. per revolution was plotted against 84.7 per cent perfect vacuum. This process was repeated for many different percentages of vacuum and the curve obtained.

The problems which may be solved with the aid of the formulas of Figs. 2 and 3 will vary in nature, but a few typical cases will be worked out in order to illustrate the application of the curves.

First and most important is the case where it is desired to determine the size of pump required to exhaust a given volume to a certain degree of vacuum in a predetermined time.

I—Given a volume of 5000 cu. ft., including the piping between the pump and tank, it is desired to find the size of pump required to exhaust the tank to a vacuum of 26 in n. i30 min. Barometer, 29.5 in.

a Assume that the pump will run at 280 r.p.m. In this case the percentage of perfect vacuum = 26/29.5 = 88.1. Using chart of Fig. 2, follow line at 88.1 per cent horizontally until it intersects the curve, then vertically downward to the base line, when the piston displacement will be found to be 10.15 cu. ft. This is the piston displacement per revolution required to exhaust 1000 cu. ft. from atmospheric pressure to 26 in. with 300 revolutions of the pump. Hence—

$$\text{Displacement per revolution} = \frac{10.15 \times 5000}{1000} \times \frac{300}{280 \times 30} = 1.814 \text{ cu. ft.}$$

This is the actual piston displacement required with a pump running at 280 r.p.m. to exhaust 5000 cu. ft. to 26 in. in 30 min. Allowance has been made for leaks such as are always present in the average installation. For xcessive leakage, however, a small factor of safety may be added.

b Assume piston displacement per revolution = 2 cu. ft. Using chart of Fig. 3, follow line at 88.1 per cent horizontally until it intersects the curve; hen vertically downward to the base line, where the number of revolutions is found to be 305. This is the total number of revolutions required to exhaust a volume of 100 cu. ft. from atmospheric pressure to 26 in. with a pump of 1 cu. ft. displacement per revolution. Hence—

$$\text{Total revolutions} = \frac{5000}{100} \times \frac{305}{2} = 7625$$

$$\text{R.p.m.} = \frac{\text{Total revolutions}}{\text{Time in minutes}} = \frac{7625}{30} = 254$$

This is the actual r.p.m. required with a pump of 2 cu. ft. piston displacement per revolution to exhaust 5000 cu. ft. to 26 in. in 30 min.

The second type of problem, the solution of which may be obtained by use of the curves, is the one in which a vacuum pump is already installed and it is desired to determine the time required to exhaust a given volume to a certain degree of vacuum.

II—Given an 18-in. by 8-in. pump running at 300 r.p.m., how long will it take to exhaust a tank of 2500 cu. ft. capacity from atmospheric pressure to 26 in. vacuum? Barometer, 28.4 in. Piston displacement per rev. = 2.34 cu. ft.; percentage of perfect vacuum = 26/28.4 = 91.5.

Using chart of Fig. 3, follow line of 91.5 per cent horizontally until it intersects the curve, then vertically downward to the base line, when the revolutions are found to be 415. This is the total number of revolutions required to exhaust a volume of 100 cu. ft. from atmospheric pressure to 26 in., with a pump of 1 cu. ft. piston displacement per revolution. Hence—

$$\text{Total revolutions} = \frac{2500 \times 415}{100 \times 2.34} = 4433.8$$

$$\text{Time required} = \frac{\text{Total revolutions}}{\text{r.p.m.}} = \frac{4433.8}{300} = 14.8 \text{ min.}$$

This is the actual time required, allowance having been made for leaks such as are present in the average installation.

In presenting this method of solving problems concerning the evacuation of closed spaces, the authors do not claim to have produced an absolutely accurate rule which will answer in every case. They do hold, however, that the method proposed of using a constant determined by trial gives much more accurate results than can be obtained by the use of an average volumetric efficiency computed by either of the two methods mentioned.

It will be noticed that the question of the effect of varying amounts of leakage on the size of pumps required has not been considered. This is undoubtedly an important phase of the problem and in any accurate determination of the size of pump or time required for evacuation, as the case may be, the leakage area of the system should be previously determined.

Obviously, if the system under consideration has two or three times the leakage area that was present in the system from which the curves of this paper were obtained, then the size of pump determined from them will be too small, or the number of revolutions required to exhaust the system in the given time will be too small. Yet even had this leakage factor been included, it is doubtful whether in the majority of cases it could be made use of.

Take the case of a purchase of a vacuum pump for evacuating a closed system. The chances are that the buyer has no means at hand for determining the leakage area before the pump ordered arrives, and it is unlikely that he would first install the closed system and have a test made on it before determining the size of pump required. This of course applies to an average commercial installation where the buyer, if he specifies a ten-minute period that he wishes to allow for the evacuation, will not care much if the pump provided actually requires, say, eight or twelve minutes in which to do the work.

The method presented is intended for such cases and it is assumed that leakage conditions will be approximately the same in a commercial installation as those under which the experiment described was made.

Feed Heating for High Thermal Efficiency

Economies of 25,000-kw. Power Stations Using Single- and Multiple-Stage Condenser Heaters, with And Without Economizers, Determined for the Purpose of Demonstrating The Effect of Varying the Feedwater Temperature

By LINN HELANDER,[1] EAST PITTSBURGH, PA.

FOR power plants using single- or multiple-stage feedwater heaters of the condenser type, the temperature of the boiler feedwater as it leaves the heaters should not be less than 150 deg. fahr. when using economizers and probably not more than 260 deg. fahr. when not using economizers, although certain conditions permit improving thermal efficiencies up to a temperature of 300 deg. fahr., corresponding to a pressure of 72 lb. per sq. in. absolute in the heater. The maximum of this range was established by consideration of fuel charges only. The lower limit of 150 deg. fahr. was chosen to avoid mechanical difficulties met when sending colder water to economizers, although this temperature, as will be seen, is less than the lowest temperature justified by purely thermal analyses of the 25,000-kw. plant used as a basis for the present studies.

That there exists for any fixed set of conditions a definite feedwater temperature at which the efficiency of power generation is a maximum is most readily demonstrated by consideration of a theoretically perfect generating plant using perfect condenser heaters. Since the feedwater heaters are considered as being perfect condensers, the pressure within them, and for the purposes of the theoretical analyses, the back pressure on the auxiliary turbine or at the extraction point on the main unit supplying the heating steam will be that corresponding to the vapor tension of the feedwater, and so will increase as the temperature of the feedwater increases. This increase in pressure in turn will increase the water rates of the steam units exhausting to the heaters, or, from another viewpoint, will decrease the work capable of being done by a pound of steam used for heating the feedwater.

Consequent upon increasing feedwater temperatures, therefore, we have a reduction in the amount of work obtainable from each pound of steam used for heating the feedwater and an increase in the total amount of steam required for heating purposes. The relation between these offsetting effects is such that the work done by the steam used for heating the feedwater increases as the temperature is increased to a certain point, after which it decreases. This is also shown by curves of Fig. 1. Any increase in feedwater temperature beyond that for which maximum work obtains continues to augment the demand for exhaust steam, but the capacity of a given quantity of the steam to do work is so reduced that the result is diminution in the total power generated by it.

Effect of Multiple-Stage Heating

A conception of what happens may be had by reference to the temperature-entropy diagrams, Figs. 2 and 3, given for both single- and double-stage heating, assuming for simplicity that saturated instead of superheated steam is used.

As the number of stages of feedwater heating increases, the work derived from the steam used for heating the feedwater increases and the temperature of the feedwater, as established for maximum theoretical efficiency, approaches that of the initial steam. Using an infinite number of stages, the temperature of the feedwater for best efficiency is equal to that of the initial steam and the efficiency of the theoretical power-generating cycle is that of Carnot's cycle.

Description of Assumed Power Station

Illustrative of what is involved in the practical problem of determining the most efficient feedwater temperatures for power stations, the effect of varying this temperature was determined for several assumed stations of 25,000 kw. capacity, using various methods of heating the feedwater. To illustrate the influence of factors such as the water rate of the main unit and the slope of the Willans line of this unit, the internal Rankine-cycle efficiency of the bled steam and the Rankine-cycle efficiencies of the house turbine, two cases—designated Case 1 and Case 2, respectively—were worked out for each arrangement of feedwater heating. The Rankine-cycle efficiency used in Case 1 for the bled steam based on the steam pressure on the turbine side of the throttle was approximately 67 per cent, slope of the Willans line was 12 lb. per kw-hr., and the water rate of the main unit when carrying the total gross station load was 10.6 lb. per kw-hr. For Case 2 the corresponding values were 80 per cent for the Rankine-cycle efficiency of the bled steam, 9 lb. per kw-hr. for the slope of the Willans line, and 10.26 lb. per kw-hr. for the water rate of the main unit.

The following are the principal data used as bases for the heat-

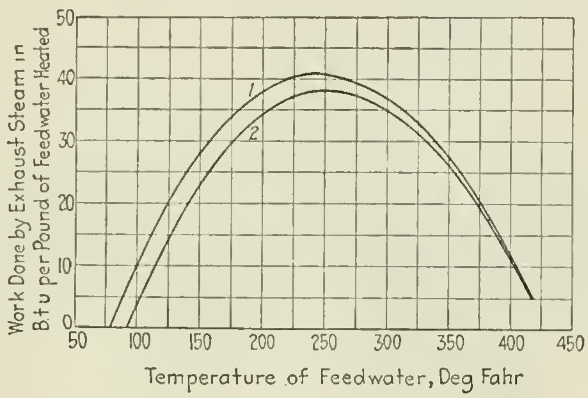


FIG. 1 WORK DONE BY EXHAUST STEAM

(Curve 1 shows for single-stage heating that the theoretical maximum work obtained from steam subsequently used for heating boiler feedwater is obtained with a final feedwater temperature of approximately 240 deg. fahr. when the initial temperature of the feedwater is 79 deg. fahr. Curve 2 is based on a condensate temperature of 92 deg. and shows that in this case the maximum work is obtained with the final feedwater temperature at 260 deg. Initial steam pressure, 325 lb.; superheat, 200 deg. fahr. The peaks of the curves establish the feedwater temperatures for maximum theoretical thermal efficiency. With two-stage heating and the same initial steam condition (condensate at 79 deg. fahr.) the maximum work is obtained at a feedwater temperature of approximately 300 deg., which theoretically, therefore, is the temperature for best thermal efficiency.)

balance study of the paper. The various formulas employed in making the study are given in an appendix to the complete paper.

Net station load....................25,000 kw.
Load on auxiliary bus....................1,300 kw.
Gross station load....................26,300 kw.
Steam consumption of the main unit when carrying the gross station load:
Case 1: 279,000 lb. per hr. Case 2: 270,000 lb. per hr.
High-pressure drips....................1000 lb. per hr.
Condensate losses....................1000 lb. per hr.
High-pressure steam losses....................3000 lb. per hr.
Radiation losses from low-pressure steam:
2 per cent of total heat in steam used for heating the feedwater
Pressure of steam at throttle....................330 lb. per sq. in. gage
Boiler pressure....................350 lb. per sq. in. gage
Superheat....................200 deg. fahr.
Heat content of boiler steam....................1326 B.t.u. per lb.
Heat content of steam at throttle....................1324 B.t.u. per lb.
Vacuum on main unit....................29 in. Hg.
Temperature of condensate....................75 deg. fahr.
Temperature of make-up water entering evaporator....................60 deg. fahr.
Slope of Willans line of main unit....................Case 1: 12 lb. per kw-hr.
Case 2: 9 lb. per kw-hr.
Heat content of the high-pressure drips recovered....................390 B.t.u. per lb.
Radiation, friction and generator losses of the house turbine in kw.:
650 kw. turbine, 65 kw. 1500-kw. turbine, 135 kw.
Radiation losses from bled steam on passing through the main unit:
1 per cent of load developed by the bled steam
Internal Rankine-cycle efficiency of bled steam based on steam pressure after throttle:
Case 1: 67 per cent. Case 2: 80 per cent
Boiler efficiency when not using economizers....................78 per cent
Boiler efficiency when using economizers but not including
the economizer efficiency....................75 per cent
Coefficient of heat transmission through economizers....................5 B.t.u. per sq. ft.
per deg. mean temperature difference between flue gases and water
Temperature of gases entering economizers....................580 deg. fahr.
Specific heat of flue gases....................0.2375
Percentage of recoverable heat recovered by economizers....................85 per cent
Flue gases per lb. of coal....................19 lb.
Heating value of coal....................13,500 B.t.u. per lb.
Ratio of the load developed by the boilers to the full-load rating of the boilers
when using economizers....................2.25

The Rankine-cycle efficiencies of the house turbines are given in

[1] General engineer, Westinghouse Elec. & Mfg. Co. Jun. Am.Soc.M.E.

Contributed by the Power Division and presented at the Annual Meeting, New York, December 4 to 7, 1922, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Abridged. All papers are subject to revision.

Figs. 4 and 5. An average value of 80 per cent was used for the Rankine-cycle efficiency of the bled steam on the main unit, though this will vary 2 or 3 per cent either way, depending on the conditions of bleeding and the design of the turbine.

All auxiliaries in these stations were considered as being motor-driven during normal operation. Surface condensers were used on the main units and the condensate before going to the feedwater heaters was passed as cooling water through the evaporator system supplying boiler-feed make-up water so long as this operated on exhaust steam. When the temperature of this exhaust steam was too low to evaporate the water efficiently and the use of live steam became necessary, the condensate was returned directly to the feedwater heater and the water used for the condenser of the evaporator was taken from the boiler feedwater previously heated in the economizers or in the feedwater heaters. With this arrangement the use of live steam on the evaporators did not materially affect the heat balance, and the pressure of the exhaust steam used for heating the feedwater was determined by the pressure within the feedwater heater rather than the requirements of the evaporator system. A schematic arrangement of these plants is shown in Fig. 6. Economizers are shown, but heat balances as well were worked out for plants not using economizers, in which case the boiler feedwater was delivered directly to the boiler.

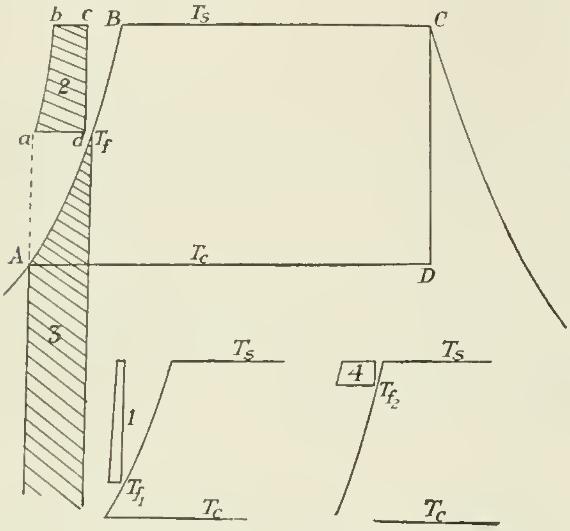


Fig. 2 Temperature-Entropy Diagram for Single-Stage Heating Using Dry Saturated Steam

(Large area $ABCD$ represents the work done by the steam passing through the main unit. The shaded area 2, above the water line, represents the work done, before entering the heater, by the steam used for heating the feedwater. The shaded area 3, below the water line, represents the heat added to the feedwater and is equivalent to the area under line ad. As indicated by areas 1 and 4 of the diagram at the bottom of the illustration, the area representing the work done by the steam used for heating the feedwater becomes rather small when the feedwater temperature deviates largely from that for best efficiency. The letters with subscripts f, f_1 and f_2 indicate the feedwater temperature for different positions of the area showing the work done by the steam usedfor heating the feedwater. The temperature of the initial steam is T_s; T_c is the temperature of the condensate.)

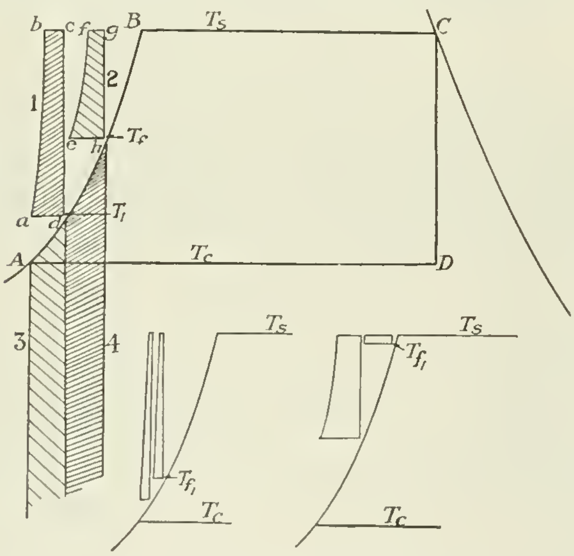


Fig. 3 Temperature-Entropy Diagram for Double-Stage Heating Using Dry Saturated Steam

(Large area $ABCD$ represents the work done by the steam passing through the main unit. Instead of a single area above the water line, as for single-stage heating, two areas, $abcd$ and $efgh$, represent the work done by the steam passing respectively to the first and second stages. For equivalent heating effects in each heater, areas 3 and 4, below the water line, are equal. The figures at the bottom of diagram show that when the feedwater temperature is rather close to either the condensate temperature or the temperature of the boiler steam, the sum of the areas representing the work done by the steam used for heating the feedwater is small. When the temperature of the feedwater equals that of the boiler steam the effect is simply that of a single-stage heater. Evidently at some temperature between that of the condensate and that of the boiler steam the sum of the areas representing the work done by the steam used for heating the feedwater is a maximum. The temperatures indicated as T_f, T_{f_1} and T_{f_2} are those of the feedwater.)

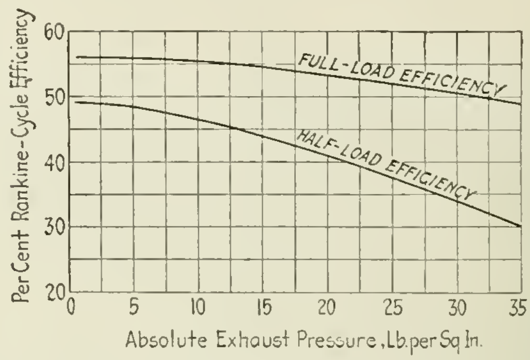


Fig. 4 Rankine-Cycle Efficiencies for Case 1

(Estimated Rankine-cycle efficiencies of 1500–1700 kw. house turbine generators as used for determining the heat balance for Case 1. The efficiencies used for the 650-kw. house turbine for Case 1 were approximately the same as those of Case 2, though the shape of its curve is similar to those given here. Steam pressure, 330 lb. gage; superheat, 200 deg. fahr.)

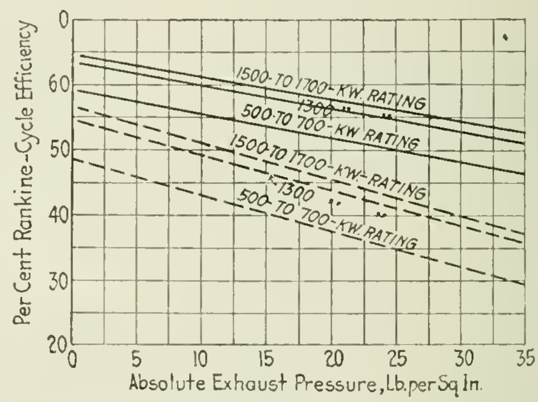


Fig. 5 Case 2. Estimated Rankine-Cycle Efficiencies of Turbine Generators Designed for Any of the Various Back Pressures and Operating against the Back Pressure for Which they Are Designed

(Steam pressure, 330 lb. gage; superheat, 200 deg. fahr. The efficiencies would deviate somewhat from those shown with back pressures below 2 lb. absolute.)

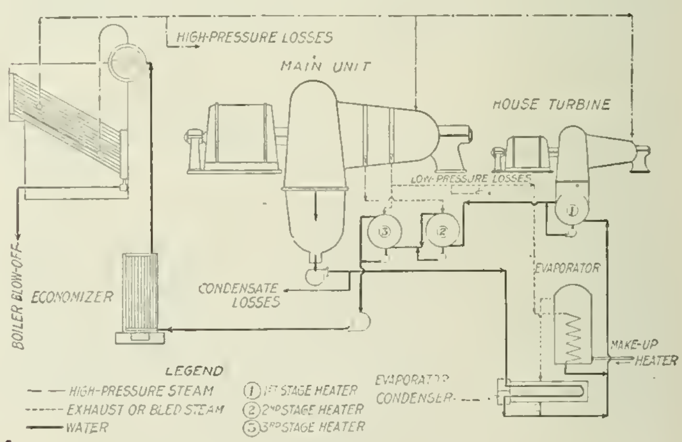


Fig. 6 Schematic Diagram of Station Layout for Three-Stage Feedwater Heating

(The condensate from the main unit is circulated through the condenser of the make-up water evaporator system before going to the feedwater heater.)

When bleeding the main unit the pressure drops in the bleeder piping varied with the amount of steam bled, and this was taken into consideration. The boilers were operated between 175 and 200 per cent of rating when economizers were not used, and under this condition had an efficiency of 78 per cent. When economizers were used the operating capacity was increased to 225 per cent of rating and the efficiency reduced to 75 per cent, not including the economizers. The power taken by the induced-draft fans was not included in the auxiliary load, and to obtain the true heat consumption for the stations using economizers the equivalent heat consumption of these fans will have to be added to the rates given.

Heat Balance for Single-Stage Heating

Heat balances for two arrangements using single-stage heating and no economizers were worked out. In one arrangement the auxiliary power was obtained from a house turbine of 650 kw. capacity, or one-half the total auxiliary load. The remainder of the auxiliary load was carried by the main unit. Steam, in addition to that supplied by the house turbine, in this case was bled from the main unit for heating the feedwater. The other arrangement used a house

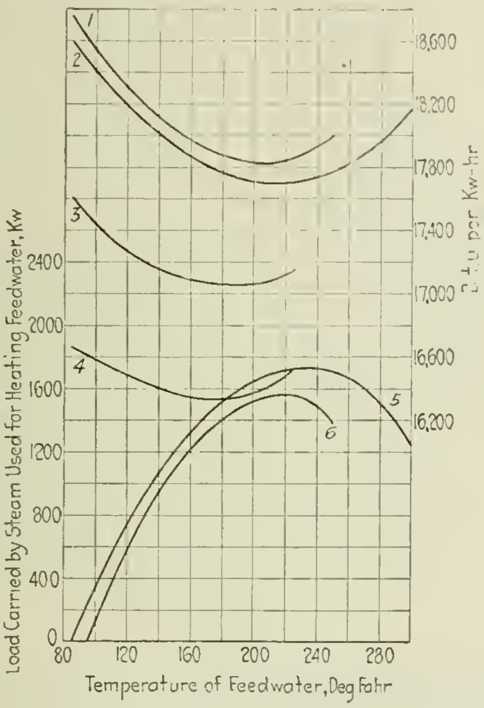


Fig. 7 Single-Stage Heating—Case 1

(Steam pressure, 330 lb. gage; superheat, 200 deg. fahr.; vacuum on the main unit, 29 in.)

Curve 1. B.t.u. per kw-hr. using a 1600-kw. house turbine and not bleeding the main unit. Economizers were not used. Feedwater temperature for best efficiency is approximately 210 deg. fahr.

Curve 2. B.t.u. per kw-hr. using a 650-kw. house turbine and bleeding the main unit. Economizers were not used.

Curve 3. B.t.u. per kw-hr. using a 650-kw. house turbine, economizer of 21,875 sq. ft. area and bleeding the main unit. Economizer surface approximately 50 per cent of the boiler area. The heat consumption of the induced draft fans, equivalent to the power consumed by them, not included.

Curve 4 B.t.u. per kw-hr. using a 650-kw. house turbine, economizer of 49,450 sq. ft. of surface and bleeding the main unit. Though the economizer area is double that for Curve 3, the feedwater temperature for best economy is reduced only 10 to 15 deg. Power taken by induced-draft fans not included with auxiliary power when determining heat-consumption curves.

Curve 5. Load developed by the steam used for heating the feedwater when using a 650-kw. house turbine and bleeding the main unit.

Curve 6. Load developed by the 1600-kw. house turbine supplying exhaust steam to the feedwater heater. A comparison of the temperature at which the peak of Curve 6 occurs with that of Curve 5 indicates the influence that decreasing Rankine-cycle efficiencies with increasing back pressures on the house turbine have on the feedwater temperature for best economy. By reference to Curves 1 and 2, showing the B.t.u. rates per kw hr., it is seen that the real influence of the decreasing Rankine-cycle efficiencies with increasing back pressures is small.

turbine with its point of best economy at 1600 kw. for Case 1 and 1700 kw. for Case 1, and was considered as being so designed that the house turbine could deliver power to the main bus. With this arrangement no means for bleeding the main unit were provided, all steam for heating feedwater being obtained from the house turbine. As indicated by the curves 1 and 2 of Figs. 7 and 8, the first arrangement is thermally the more economical and also requires for best efficiency a slightly higher feedwater temperature than the second arrangement. It is interesting to note that whereas the theoretical feed temperature for best efficiency was in the neighborhood of 250 deg. fahr., the actual temperature is closer to 200 deg. fahr. This is due to various factors, among them being the decreasing Rankine efficiency of house turbines when operating at successively higher back pressures.

Heat Balance for Double-Stage Heating

Similarly heat balances for two arrangements using double-stage heating and no economizers were worked out on the basis that the heating effect was divided equally between the two stages. In

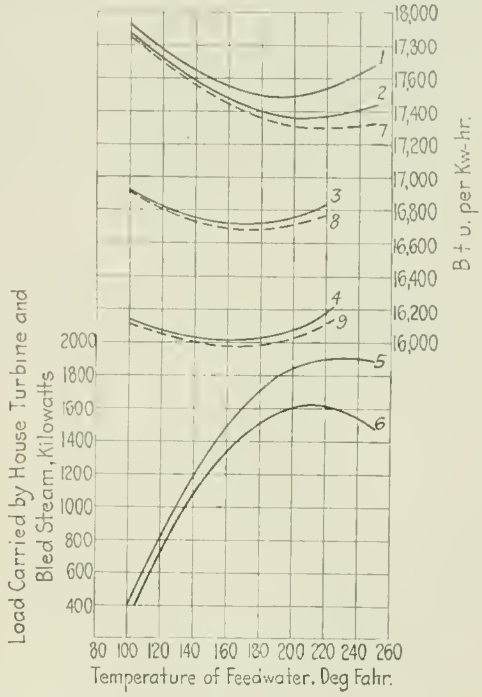


Fig. 8 Single-Stage Heating—Case 2

(Steam pressure, 330 lb. gage; superheat, 200 deg. fahr.; vacuum on the main unit, 29 in.)

Curve 1. B.t u. per kw-hr. using a 1700-kw. house turbine and not bleeding the main unit. Economizers not used. The feedwater temperature for best economy is approximately 190 deg. fahr. This is 20 deg. lower than the best feedwater temperature for the corresponding conditions of Case 1, though due to the flatness of the curves over this range, the proper temperature for either case may be considered as approximately the same. The difference in temperature indicated is due to the difference in the slopes of the Rankine-cycle efficiency curves for the house turbine.

Curve 2. B.t.u per kw-hr. using a 650-kw. house turbine and bleeding the main unit not using economizers.

Curve 3 B.t.u. per kw-hr. using a 650-kw. house turbine, economizer of 21,875 sq. ft. area, and bleeding the main unit. The feedwater temperature for best economy is lower than the corresponding temperature for Case 1, due largely to the difference between the slopes of the Willans lines of the main units. Power consumed by induced-draft fans not included in auxiliary power.

Curve 4. B.t.u. per kw-hr. using a 650-kw. house turbine, economizer of 49,450 sq. ft. of surface, and bleeding the main unit. Power consumed by induced-draft fan was not included in auxiliary power.

Curve 5. Load developed by the steam used for heating the feedwater using a 650-kw. house turbine and bleeding the main unit.

Curve 6. Load developed by the 1700-kw. house turbine supplying exhaust steam to the feedwater heater.

Curve 7. Same as Curve 2 except that low-pressure steam losses are neglected.

Curve 8. Same as Curve 3.

Curve 9 Same as Curve 4 except that low-pressure steam losses are not included.

one of these arrangements the first-stage heaters derived the steam for heating the feedwater from a house turbine with its point of best economy at 1400 kw. for Case 1 and 1500 kw. for Case 2, only the second-stage heater deriving steam by bleeding the main unit. The other arrangement used a house turbine with its point of best economy at 650 kw., additional steam required by the first-stage heater being obtained by bleeding the main unit. The feedwater temperatures for best efficiency as indicated by curves 1 and 2 of Figs. 9 and 10 are seen to be approximately the same in either case, and about 25 deg. below that indicated by theoretical considerations alone. Both curves are rather flat over a range of 50 deg. in the vicinity of the point of best efficiency. The more efficient of the two arrangements, as with single-stage heating, is that one using the smaller house turbine, or the one bleeding the largest amount of steam from the main unit. This latter arrangement, with feedwater temperature of 275 deg. fahr., showed a possible saving of approximately 320 B.t.u. per kw-hr. as compared with single-stage heating. The maximum efficiency using single-stage heating, however, was obtained with a feedwater temperature of approximately

200 deg. fahr. Comparing single-stage with double-stage heating on the basis that this temperature of 210 deg. fahr. was not to be exceeded, the difference between double-stage and single-stage heating is about 225 B.t.u. per kw-hr.

Effect of Economizers

Economizers in connection with single- and double-stage heating were applied to those stations which used a 650-kw. house turbine and bled the main unit this arrangement being the more economical. The economizers were assumed as having a heat-recovery factor of 85 per cent and a heat-transfer rate of 5 B.t.u. per hour per deg. mean temperature difference between the flue gases and the water. Two sizes of economizers were applied to each station to illustrate the effect of varying the size of the economizers. The boilers, as previously stated, were assumed to operate at approximately 225 per cent of their rated capacity, and their efficiency in this case was taken as 75 per cent, or 3 per cent less than that used when the stations had no economizers. The temperature of the flue gases entering the economizers in all cases was taken as 580 deg. fahr., which meant that for the type of boilers selected the percentage of rated capacity developed did not vary with the temperature of the feedwater. This, of course, required that the total operating capacity be slightly decreased as the temperature of the feedwater entering the boiler was increased. The weight of the flue gases per pound of coal burned was taken as 19 lb. and independently of the feedwater temperature, but, inasmuch as the weight of coal burned per pound of steam generated varied with the feedwater temperature, the weight of gas per pound of steam generated likewise varied.

Analyses of heat balances as affected by feedwater temperatures did not involve considerations of boiler-room efficiency for those stations not using economizers. When economizers were used, however, the temperature of the flue gases leaving the economizer, for given equipment and operating conditions, was determined by the temperature of the water entering the economizer. Increasing the temperature of the water entering the economizer simultaneously increased the temperature of the flue gases so that the combined efficiency of the economizers and boilers was decreased. However, as the temperature of the feedwater leaving the heaters was increased above that of the condensate, the efficiency of converting steam to power, as previously demonstrated, increased, thereby opposing the consequent decrease in efficiency of steam generation. The relative rates at which the efficiency of steam generation decreased and that of power generation increased determined the temperature of the feedwater for best efficiency, these rates being equal for the condition of best efficiency. The rate at which the efficiency of steam generation decreases with increase in feedwater temperatures depends on the relative area of the economizers and the boilers. The larger the economizer relative to the boiler, the more rapid is the rate at which this efficiency falls off. In consequence of this, the feedwater temperatures for best efficiency were found to be lower for the larger economizers than for the smaller ones, though the differences were not of great moment.

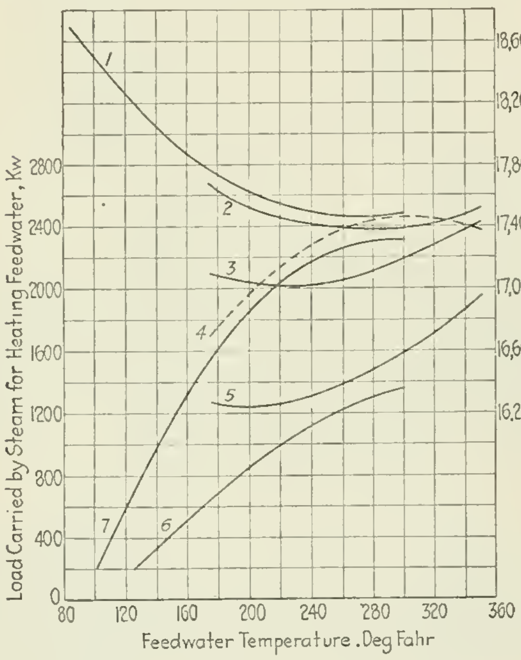


Fig. 9 Double-Stage Heating—Case 1

(Steam pressure, 330 lb. gage; superheat, 200 deg. fahr.; vacuum on the main unit, 29 in.)

Curve 1. B.t.u. per kw-hr. using a 1400-kw. house turbine and bleeding the main unit to obtain steam for the second stage, not using economizers. The feedwater temperature for best economy is approximately 280 deg. fahr.

Curve 2. B.t.u. per kw-hr. using a 650-kw. house turbine and bleeding the main unit at two points, not using economizers. It is noticeable that as the number of stages used for heating the feedwater increases, the curve of heat consumption per kw-hr. flattens out.

Curve 3. B.t.u. per kw-hr. using a 650-kw. house turbine, economizer of 18,180 sq. ft. area and bleeding the main unit at two points. Economizer surface approximately equivalent to 45 per cent of boiler area. Power taken by induced-draft fans not included in the auxiliary load.

Curve 4 (dotted). Load developed by steam used for heating feedwater when using a 650-kw. house turbine and bleeding the main unit at two points.

Curve 5. B.t.u. per kw-hr. using a 650-kw. house turbine, economizer of 47,000 sq. ft. area and bleeding the main unit at two points.

Curve 7. Load developed by the steam used for heating the feedwater when using a 1400-kw. house turbine and bleeding the main unit only for the second-stage heating. Curve 6 shows the load carried by the house turbine for this arrangement of heating the feedwater.

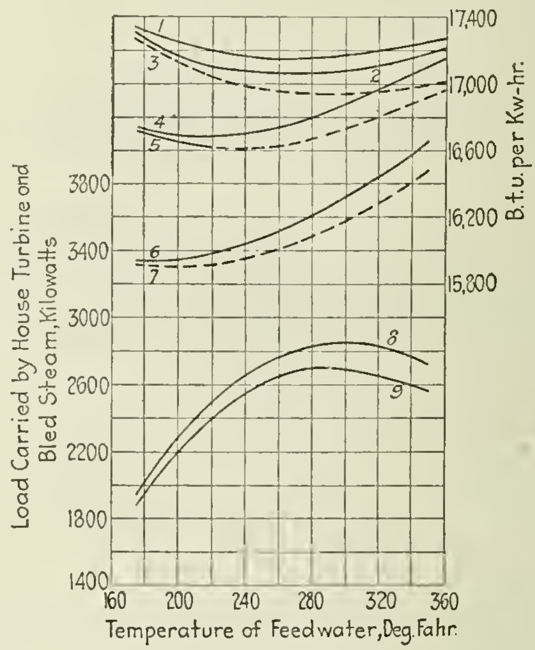


Fig. 10 Double-Stage Heating—Case 2

(Steam pressure, 330 lb. gage; superheat, 200 deg. fahr.; vacuum on the main unit, 29 in.)

Curve 1. B.t.u per kw-hr. using a 1500-kw. house turbine and bleeding the main unit to obtain steam for the second stage, not using economizers. The feedwater temperature for best economy is approximately the same as for the same conditions of Case 1.

Curve 2. B.t.u. per kw-hr. using a 650-kw. house turbine and bleeding the main unit at two points, not using economizers. Curve 3 is the same except that losses due to leakage from the low-pressure steam piping are not included.

Curve 4. B.t.u. per kw-hr. using a 650-kw. house turbine, economizer of 18,180 sq. ft. area and bleeding the main unit at two points. The feedwater temperature for best economy is slightly lower than for Case 1. The power taken by the induced-draft fans was not included in the auxiliary power load. Curve 5 is the same but does not include the low-pressure steam losses.

Curve 6. B.t.u. per kw-hr. using a 650-kw. house turbine, economizer of 47,000 sq. ft. area and bleeding the main unit. The feedwater temperature for best economy is lower than for Case 1, due to difference in the slope of the Willans lines of the main units. Curve 7 is the same but does not include the low-pressure steam losses.

Curve 8. Load developed by the steam used for heating the feedwater when using a 650-kw. house turbine and bleeding the main unit at two points.

Curve 9. Load developed by the 1500-kw. house turbine when used to supply steam for feed heating in conjunction with bleeding the main unit.

The temperature for best economy when economizers are used, as given by the heat-consumption curves 3 and 4 of Figs. 7 and 8 for single-stage heating, lies between 175 and 190 deg. fahr. for Case 1 and 165 and 175 deg. fahr. for Case 2. With double-stage heatings, Figs. 9 and 10, the corresponding temperatures are 225 and 175 deg. fahr. for the smaller and larger economizer surfaces, respectively, for Case 2, and 230 and 200 deg. fahr. for Case 1. The temperatures for Case 1 are lower than those for Case 2, due to the difference in the slopes of the Willans lines used. For each kilowatt-hour developed by the steam used for heating the feedwater in Case 1, the steam condensed in the main unit's condenser was reduced

12 lb., while for Case 2 this figure was 9 lb. The benefit derived from carrying load on steam used for heating the feedwater was therefore relatively less for Case 2 than for Case 1, while the economizer and boiler efficiency remained the same. The differences in temperature are small, however, and indicate that with fair accuracy the desirable feedwater temperature may be considered as a range which is largely independent of the characteristics of the steam equipment used. The economizers used for double-stage heating were slightly smaller than those used for single-stage heating, commercial considerations indicating that this was justified. The difference in the sizes of the economizers did not, however, materially affect the feedwater temperature for best efficiency. The rate-of-heat-consumption curves are rather flat over a considerable range in proximity to the temperature for best economy, and increasing the area of the economizers even to the extent of doubling them need not require large changes in the temperature of the feedwater. The various data used in connection with the economizers are given in curves in the complete paper.

Comparison of Results With and Without Economizers

A comparison of feedwater temperatures for best economy as indicated by Case 1 and Case 2, respectively, shows that when economizers are not used ordinary variations in the Rankine-cycle efficiency of the bled steam, the efficiency curve for the house turbine, and the slope of the Willans line of the main unit have no considerable effect. When economizers are used, the temperatures are reduced by decreasing the slope of the Willans line of the main unit, but, as previously stated, the influence is not large. It is evident that for the purpose of establishing the proper feedwater temperature for best economy minute accuracy in the determination of the various turbine efficiencies is not required. The overall efficiency of the entire station is influenced, of course, by these efficiencies, but the best feedwater temperature changes only slightly with them. For this study a constant efficiency for bled steam was used. However, the house-turbine efficiencies were considered as being a function of the feedwater temperature, and a comparison of the temperatures for best economy obtained when using a house turbine alone with those obtained when using a smaller house turbine together with bleeding the main unit illustrates the influence of the variation in the Rankine-cycle efficiency. The difference in the temperatures that were obtained is between 10 and 15 deg. fahr., but inasmuch as the curves are flat this is of no great consequence.

Multiple-Stage Heating

By similar methods of computation, heat balances for four-stage heaters with and without the use of economizers were determined. The average Rankine-cycle efficiency for the bled steam in this case was taken at 79 per cent instead of 80 per cent, as the average efficiency over four stages would probably be somewhat less than that for one stage. Fig. 11 shows the heat consumption per kilowatt-hour for the various methods of heating the feedwater worked out for Case 2, using the 650-kw. house turbine. As the number of heating effects increase, the value of the last effect decreases, which is to be expected. It is interesting to observe also that as the number of effects increase, the heat-consumption curves for the various stations flatten out in proximity to the temperature for best economy and that it would therefore seem undesirable to go beyond a certain feedwater temperature regardless of the number of stages. When economizers of 21,850 sq. ft. are used the gains in efficiency referred to a basis of no heating for single-, double-, triple-, and quadruple-stage heating are 1.86, 2.88, 3.35, and 3.64 per cent, respectively. When the number of heating effects is increased the value of the last heating decreases, and in determining the proper number of stages consideration must be given to the investment and also to the operating problems encountered.

Air Economizers

If air for the boilers is preheated by means of air economizers and no feedwater economizers are used, such preheating does not affect the feedwater temperature for best economy. However, the air may be preheated by exhaust steam similarly to heating feedwater. Also air economizers and exhaust-steam air heating may be used with or without the coincident use of water economizers, and with single- or multiple-stage feedwater heating. If air is heated by exhaust steam alone, the problem of determining its temperature for maximum efficiency is not different from that for determining the temperature of feedwater heated only by exhaust steam. This, however, is not the case if both air and water economizers are used simultaneously.

Air and water economizers, if used simultaneously, may be placed either in parallel or in series. If placed in parallel the effect of the air economizer is to reduce the amount of gases available for heating the feedwater, and so alter the operating characteristics of the water economizers so far as these are determined by the ratio of the waste gases to the water heated. If the air heater is placed in series with the water economizer and in the coldest part of the flue gases, the leaving temperature of these gases is no longer determined by the temperature of the boiler feedwater. For such an arrangement it would appear desirable to heat the boiler feedwater to that feedwater temperature giving the maximum efficiency for the conversion of steam energy to electrical power. The feedwater would then be further heated in a water economizer while the temperature of the flue gases leaving the water economizer could be reduced to a desirable point, justified, of course, by the efficiency of the air economizers and their cost. On this basis the temperature of the feedwater entering the economizers would correspond to that previously determined when no economizers were used. The air

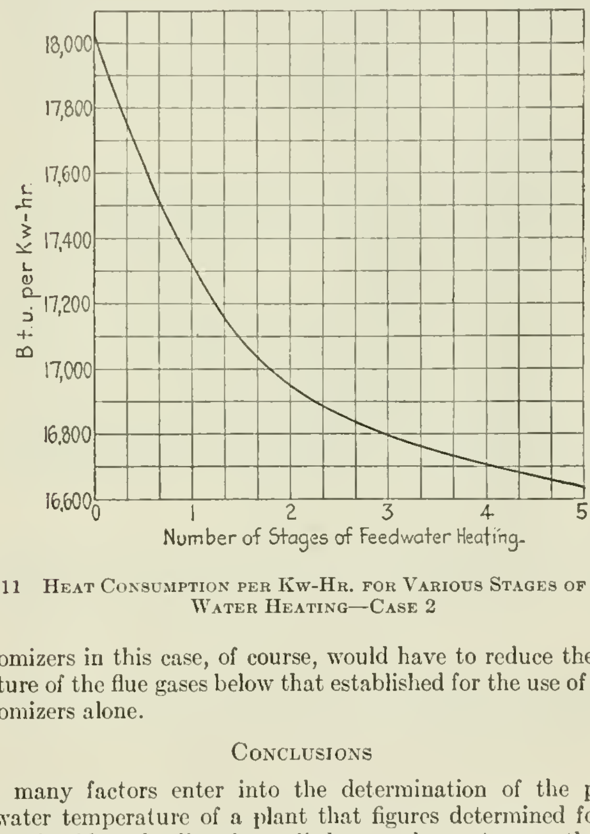


Fig. 11 Heat Consumption per Kw-Hr. for Various Stages of Feed-Water Heating—Case 2

economizers in this case, of course, would have to reduce the temperature of the flue gases below that established for the use of water economizers alone.

Conclusions

So many factors enter into the determination of the proper feedwater temperature of a plant that figures determined for one station should not be directly applied to another. As seen, the temperature should be lower for plants using single-stage heating than for those using multiple-stage heating, and also should be lower for plants using economizers than for plants not using economizers. Efficiencies of auxiliary apparatus as well as of the main generating units have their influence. If the feedwater temperature be raised much above 212 deg. fahr., factors incident to the use of pressures well above atmosphere in the auxiliary exhaust piping come into play. The proper feedwater temperature is dependent somewhat upon the initial steam pressure and temperature and on the temperature of the condensate, increasing as these increase. It is quite impossible, therefore, to determine, except within wide limits, feedwater temperatures applicable to all plants, and the present purpose has been rather to indicate in a broad way the effect of feedwater temperatures on power-plant efficiency, leaving out the matter of costs, and to give some basis for estimating the sacrifice in fuel made to assure practicable operation of the feedwater-heating system as laid out for a particular station.

Lumber Dry Kilns

By THOMAS D. PERRY,[1] GRAND RAPIDS, MICH.

The three main divisions into which lumber dry kilns may be grouped are blower, condenser, and ventilated kilns. The author, who believes that scientific kiln drying offers engineers a splendid field for research work, describes these types and discusses the possibilities of each, with particular reference to the ventilated kiln, of which there are several classes. The questions of moisture deficit and equilibrium, air interchanges, and drying cycles are adequately treated, and data showing the relation between relative and absolute humidity during the drying period are included.

THE PROBLEM presented to the manufacturer who would utilize woods intelligently is a diversified one owing to the fact that the score or more of major varieties of commercial timbers are grown in climates and seasons differing widely in temperature and moisture, and on soils ranging from the rocky hills of the Appalachians to the rich alluvial lowlands of the Mississippi delta. The origin of the lumber, has a noticeable effect on its water content. Lumber or veneer (thin lumber produced usually by rotary cutting or flat slicing, sometimes by sawing), when produced from the log, contains a large proportion of water, ranging from 25 to 75 per cent of the total weight. One square foot (board measure, one inch thick) of gum lumber, weighing approximately five pounds when sawed, will be reduced to about three pounds when its water content of approximately one quart has been evaporated. Oak grown on a hillside may contain only a pint (approximately 1 lb.) and swamp gum may have from 2 to 4 pints of water per sq. ft. B. M.

This water content of wood exists in two forms, free moisture and cell moisture, the former being readily evaporable in ordinary air drying, and the latter demanding excessive air drying (several years) or artificial treatment in kilns. The usual border line between the two forms of moisture is in the vicinity of 30 per cent moisture content (the percentage of the weight of water removed being computed on the dry fiber weight as a base). It is possible to use artificial means to remove this free moisture, but a simple air exposure is usually more economical.

By far the largest volume of lumber products are dried in the form of lumber or veneer. The drying of unusual forms and shapes, such as staves, handles, shingles, laths, etc., is decidedly specialized and outside the range of this discussion.

Types of Kilns

The original artificial drier was a smoke kiln, now practically obsolete. This was followed by the furnace kiln and the steam-coil kiln. Some woodworkers still persist in using home-made equipment, but kiln design and building has become a special branch of manufacturing that has its own recognized field.

The three main divisions into which lumber kilns may be grouped, as illustrated in Fig. 1, are:

1 Blower: Mechanically forced ventilation, or recirculation, whether suction or plenum method; moisture-laden air usually discharged out of doors

2 Condenser: Generally of the gravity recirculating type, in which the air passes over moisture-removal or condensing units, once in each interchange

3 Ventilated: Fresh air taken in and used air discharged direct from kiln to atmosphere, utilizing the fundamental laws of physics to obtain internal circulation.

To understand the particular range of each of the foregoing types it is necessary to outline the moisture-removal problem in some detail from the standpoint of the lumber to be dried. Air drying removes more moisture from the surface than from the center, and owing to the length and width of a board, drying takes place chiefly through the flat faces, rather than through the ends or edges. The inevitable result is a surface drier than the interior, and air-dried stock is therefore subject to an internal strain that often manifests itself in the form of warp, twist, or other surface irregularities. The problem is to draw the center moisture out and have surface and interior equally dry.

The skill of an engineer is not required to discover that, if the drying of wood afforded no organic difficulties, the blower would dry rapidly, utilizing considerable power, and the condenser would function slowly but at low cost.

The ventilated kiln is the least understood, even though most generally used, and offers an unusual opportunity for speed and efficiency when its underlying principles are grasped.

The nature of wood is the phase of the problem that engineers least appreciate. It is almost axiomatic that wood should not be subject to external or internal strain during drying, but it is practically impossible to obtain such a "strainless" condition. The reduction of this drying strain to a minimum point is necessary to drying without damage to the lumber, the usual manifestations of which are checking, warping, honeycombing, "hollowhorning," etc. The chance of internal strain greatly increases with the thickness of the wood to be dried: e.g., $^1/_{16}$-in. veneer is practically all surface and can develop little internal strain in any kind of drying, while 4-in. green oak presents a decidedly stubborn drying problem, and taxes the skill of the best operator in an efficiently controlled kiln.

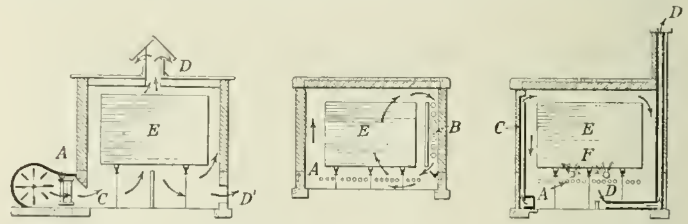


Fig. 1 Showing (from Left to Right) Blower, Condenser and Ventilated Kilns

(*A*, Heating unit; *B*, condensing unit; *C*, fresh-air inlet; *D* and *D'*, used-air outlets; *E*, lumber charge; and *F*, humidifying unit.)

Blowers and Condensers

These facts lead to the logical conclusion that where thickness is nominal, as in the case of veneer, applied shellac, stain, filler, varnish, and glue, the speed of the air movement in a blower kiln will remove moisture rapidly and cause no serious damage; but where thickness becomes appreciable ($^1/_2$ in. and up) the rapidly moving atmosphere of a blower kiln will produce uneven drying and unnecessary interstrain that will inevitably damage the lumber. Even with attempted maintenance of high humidities (difficult in blower kilns[1]) the hazard is serious. On the other hand, the slowness of the condensing kiln will make for accurate control, but the lack of speed may force the initial cost of installation to an excessive amount. As a matter of fact, Government experts have frequently recommended the condensing kilns without comprehending in most cases the economic aspect. It has been the author's experience during the last five years that kilns of the condensing type used for war work did no better drying than the best of the ventilated types, and required for an equivalent output practically twice as many units, at approximately double the initial cost per unit, or a quadruple investment, with no appreciable gain in quality or safety.

As a conclusion it may be noted that blower kilns are most suitable where thickness is not a factor, and that condenser kilns are especially serviceable in the drying of thick green woods where internal strain is a decided danger.

Typical Drying Cycle

Before considering the individual characteristics of the various types of ventilated kilns, it may be well to outline briefly a drying cycle. Take an actual operation schedule, tested by practice,

[1] Vice-president and manager, Grand Rapids Veneer Works. Assoc-Mem. Am.Soc.M.E.

Contributed by the Forest Products Division for presentation at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. All papers are subject to revision.

[1] Kent's Mechanical Engineers' Pocket Book, 1916 edition, p. 573.

of reducing 1-in. oak from 35 to 5 per cent moisture content in 16 days of 24 hours steam. Plotting this schedule, curves showing the variations in temperature and the relative humidity during the period of drying are obtained as shown in Fig. 2. The drying cycle divides itself into three phases: initial "steaming" or high-humidity period in which lumber is heated through and enough moisture added to make the surface as wet as the center; intermediate "stewing" or cooking,[1] a transition period; and the final "drying," when humidity may be dropped and temperature raised within limits demanded by the kind and condition of lumber.

The temperature should gradually rise from 125 to 170 deg. fahr. and care should be exercised that it does not go up too fast during the initial steaming, which would tend to crust the outside of the boards. The relative-humidity line reaches 100 per cent as rapidly as possible without producing an excess of temperature. The reason for the high initial humidity is that partly dried lumber, as placed in the kiln for drying, normally has a surface drier than the interior, and unless the surface is thoroughly moistened the internal moisture will be sealed in by the dry and shrunken surface layers; in other words, the degree of internal strain will be intensified rather than

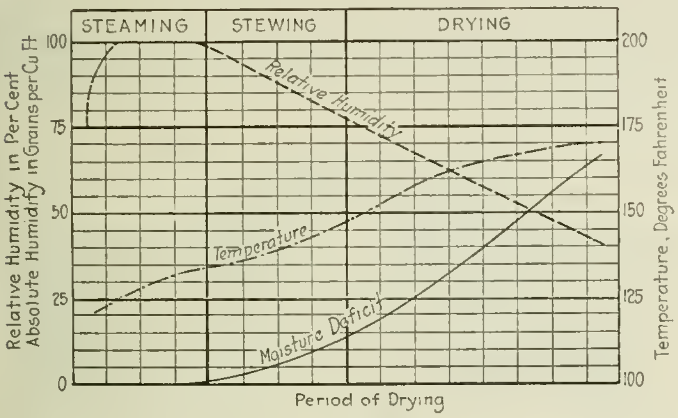


Fig. 2 Temperature and Relative Humidity During Drying Cycle and Curve Showing Moisture Deficit

reduced. If the surface of the board is steamed or exposed to an atmosphere of high humidity it will absorb moisture and expand, making it possible for the cellular structure to conduct additional moisture to the surface, and reducing the internal strain. Heating the lumber through is also accomplished quickly and safely by this steaming.

Moisture will pass out more rapidly from the surface of a board the center and surface of which are approximately equal in moisture content, and the final result of the drying cycle will be a reasonably uniform moisture content from face to face of the board and an absence of internal strain, with consequent damage. It is a rather significant fact that lumber dried by the so-called "wet" process explained in the preceding paragraph is more plump than when treated by the old-fashioned method of "giving it all the heat it will stand" without preliminary steaming or due regard to the humidity. Experiments have proved that the endeavor to dry without steaming takes longer because moisture transfuses more slowly through a dry than a wet surface, and the resulting damage is usually serious.

Relative vs. Absolute Humidity—Moisture Deficit

Another way of expressing the function of humidity is to express the cycle of drying from the standpoint of absolute humidity, or the grains of water vapor per cubic foot of atmospheric kiln content. Table 1 shows the relation of absolute (grains of water per cubic foot) and relative humidity (percentage of saturation) within the usual ranges of kiln temperature.

If we could isolate and examine a cubic foot of space (containing air and water vapor) in a kiln at a temperature of 150 deg. fahr. and a relative humidity of 50 per cent, we would find that it contains 36.76 grains of water in the form of vapor and possesses the capacity, before reaching saturation, of absorbing an equal additional amount of water vapor. It is this difference between actual grainage and the grainage of saturated water-vapor content that expresses the drying power of the kiln.[2] Stated in another way, this means that a cubic foot partly saturated has a tendency to become entirely saturated if free moisture is accessible, i.e., from the lumber.

This moisture deficit may be termed the measure of drying power in a kiln (when considered in connection with the temperature and circulation) and the greater the deficit the greater will be the pull exerted on the moisture contained in the lumber. At the beginning of the drying operation, when reducing the lumber to a uniform wetness, the moisture deficit is nil; and toward the end of the operation, at a temperature of 170 deg. fahr. and a relative humidity of 40 per cent, each cubic foot is eagerly seeking for 67 grains of water vapor or such part of it as can be extracted from the lumber. Fig. 2 contains a curve showing the moisture deficit expressed in grains per cubic foot. It will be noted that this line curves up more rapidly than the temperature line. This moisture deficit may be termed the measure of potential drying power. It is easy to remove moisture from the lumber at first, but the last few stages of drying require a decidedly strong pull.

While it would be possible to reduce the relative humidity to below 40 per cent (carrying the moisture deficit above 67 grains), it would result in too rapid a rate of surface drying and leave an unevenly dried product. The secret of controlling temperature and humidity in efficient drying is to avoid any sudden changes during the progress of the operation and to finish without carrying the temperature to an extreme that will damage the wood; and to avoid reducing the relative humidity at any point where it will dry the surface faster than the center.

Air Interchanges

The number of air interchanges per hour should not be too great. If an anemometer test shows three or four complete air changes per hour, it is enough. The process of the withdrawal of water

TABLE 1 GRAINS OF WATER VAPOR PER CUBIC FOOT AT VARIOUS RELATIVE HUMIDITIES[3]
(7000 grains = 1 lb. avoirdupois)

Temperature, Deg. Fahr.	Relative Humidity																			
	5%	10%	15%	20%	25%	30%	35%	40%	45%	50%	55%	60%	65%	70%	75%	80%	85%	90%	95%	100%
100	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
105	1	2	3	5	6	7	8	9	10	11	13	14	15	16	17	18	19	21	22	23
110	1	3	4	5	7	8	9	10	12	13	14	16	17	18	20	21	22	24	25	26
115	2	3	5	6	8	9	11	12	14	15	17	18	20	21	23	24	26	27	29	30
120	2	3	5	7	9	10	12	14	15	17	19	20	22	24	26	27	29	31	32	34
125	2	4	6	8	10	12	14	16	18	20	22	23	25	27	29	31	23	35	37	39
130	2	4	7	9	11	13	15	18	20	22	24	26	29	31	33	35	37	40	42	44
135	3	5	8	10	13	15	18	20	23	25	28	30	33	35	38	40	43	45	48	50
140	3	6	8	11	14	17	20	23	25	28	31	34	37	39	42	45	48	51	54	56
145	3	6	10	13	16	19	22	26	29	32	35	38	42	45	48	51	54	58	61	64
150	4	7	11	14	18	21	25	29	32	36	39	43	46	50	54	57	61	64	68	72
155	4	8	12	16	20	24	28	32	36	40	44	48	52	56	60	65	69	73	77	81
160	4	9	13	18	22	27	31	36	40	45	49	54	58	63	67	72	76	81	85	90
165	5	10	15	20	25	30	35	40	45	50	55	60	65	71	76	81	86	91	96	101
170	6	11	17	22	28	34	39	45	50	56	61	67	73	78	84	89	95	101	106	112
175	6	12	19	25	31	37	44	50	56	62	69	75	81	87	94	100	106	113	119	125
180	7	14	21	28	34	41	48	55	62	70	76	83	90	97	103	110	117	124	131	138
185	8	15	23	31	38	46	54	61	69	77	84	92	100	107	115	123	130	138	146	153
190	8	17	25	34	42	51	59	68	76	84	93	101	110	118	127	135	144	152	160	169
195	9	19	28	37	47	56	65	75	84	94	103	112	122	131	140	150	159	168	178	187
200	10	21	31	41	51	62	72	82	92	103	113	123	133	144	154	164	175	185	195	205

[1] "Stewing" used in the sense of a vapor bath, rather than as cooking (212 deg. fahr). Some authorities merge this into the "drying period."
[2] It is obvious that the higher the temperature, with a given moisture deficit, the more rapid the evaporation.
Adapted from tables compiled by Dr. William M. Grosvenor, with intermediate readings interpolated and decimals discarded.

vapor from the interstices of the lumber cannot be very rapid. Too rapid air movement in a gravity kiln subjects it to the same criticism as a blower kiln, i.e., too rapid surface drying.

High humidity and large circulation of air are antithetical to one another. To obtain high humidity, the circulation must be either stopped altogether or greatly reduced, and to reduce the humidity a greater circulation must be induced by increasing the draft.

The following example, based on three interchanges per hour, illustrates this point:

Size of kiln inside	15 ft. high by 19 ft. wide by 26 ft. long
Cubic contents, gross	7410 cu. ft.
Lumber allowance	1083 cu. ft. (13,000 ft. B. M.)
Equipment allowance	50 cu. ft.
Cubic contents, net	6277 cu. ft.

Allowing a moisture-lifting capacity averaging 25 grains of water vapor per cu. ft. of each discharge from the kiln:

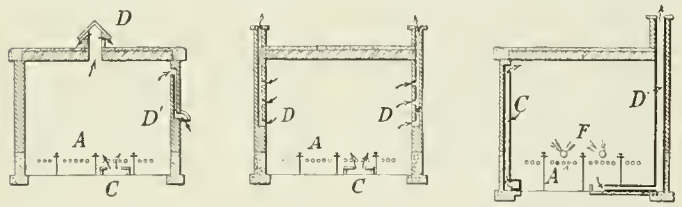


Fig. 3 Classes of Ventilated Kilns
(From left to right, ventilated at top, side and bottom. *A*, heating unit; *C*, fresh-air inlet; *D* and *D'*, used-air outlets; and *F*, humidifying unit.)

Discharge per cu. ft.	25 grains or 0.00357 lb. avoirdupois
Total single discharge	0.00357 × 6277 = 22.42 lb.
Hourly discharge (3)	67.26 lb.
Daily discharge (72)	1614.25 lb.

Estimating the average water content of saturated oak lumber at 1 lb. per ft. B. M.:

Lumber allowance	13,000 ft. B. M.
Moisture to be removed	13,000 lb.
Time required	13,000 ÷ 1614 = 8.05 days

This would indicate that the actual drying period (Fig. 2) will require practically eight days if the texture of the lumber permits of an average removal of 25 grains. An additional time allowance should be made for steaming.

The removal of 2 lb. moisture per ft. from green gum, for instance, would necessitate either increasing the drying time proportionately, or operating at a higher temperature.

Moisture Equilibrium

Theoretically it may be possible to reduce lumber to absolute dryness, but it cannot be kept so except in sealed receptacles. Under ordinary factory-workroom conditions, it will reabsorb to 6 or 8 per cent moisture. It is necessary, therefore, only to dry down below normal and allow for reabsorption. In ordinary lumber yards the lumber will rarely air-dry below 15 per cent, and kiln-dried stock left out of doors will absorb to about the same point. For structural purposes, exposed to weather the moisture content of timbers should be around 15 per cent to prevent shrinkage or expansion. For more accurate work the equilibrium point should be ascertained for each plant and will be found for interior trim to be about 8 to 10 per cent and for furniture, pianos, etc., from 4 to 7 per cent.

Ventilated Kilns

Ventilated kilns are readily grouped into three classes as indicated in Fig. 3.

Kilns of the first class are ventilated at the *top*, either through the ceiling and a cupola on the roof, or through openings in the side walls near the ceiling. Fresh air is usually admitted near the floor and the air movement must be distinctly upward. The real problem is to obtain an efficient utilization of this air movement to lift moisture out and up from the lumber.

No difficulty will be encountered in securing ample air discharge, as hot air will always rise and seek an exit. It is obvious that the hot air escaping will not be heavily charged with moisture. Only to a limited extent is it possible to use this upward-moving air as a moisture vehicle, because the increased water-absorption capacity accompanying higher temperatures will carry only a small amount of water vapor without a net increase in weight.

As an example, suppose the temperature of the air in the lower part of the kiln is 140 deg. fahr. and at the top 160 deg. fahr.; dry-air weights, 463.09 and 448.11 grains per cu. ft., respectively, a difference of 14.98 grains (less than 20 per cent relative humidity at 160 deg.). Air, therefore, cannot move upward and carry as much as 15 grains (neglecting expansion which is less than 4 per cent). Compare this with the fact that in a down-draft kiln the air at 140 deg. can carry 56 grains per cu. ft. before reaching saturation.

Any steam spray in this type tends to monopolize the limited moisture deficit of the kiln air and to greatly decrease the drying power as the air circulates upward through the lumber.

The second class have air exits at the *sides* and air inlets usually at the bottom. There is less of a scientific basis for this type than for either the first or the third type. There is great danger of "short-circuiting" the air across a corner of the kiln, thus causing pockets in places where a lack of air movement prevents drying. When this type is applied to the primary drying (to reduce shipping weight) at sawmills, with high temperatures, it may give fair results in regard to the removal of free moisture, and perhaps will reduce the moisture content to 15 per cent, but below this point it is undependable.

The use of steam spray or the handling of relatively moisture-laden atmosphere is no more possible than in the first

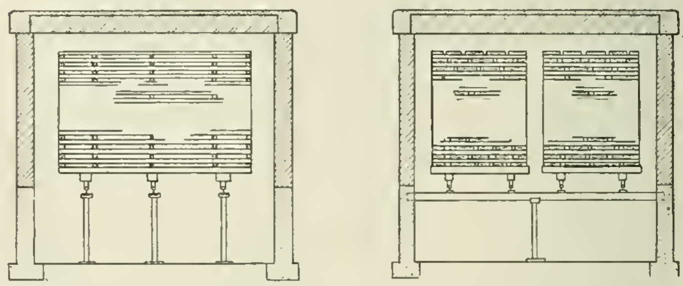


Fig. 4 Transverse Section of a Kiln, Showing Cross-Pile (at Left) and End-Pile (at Right)
(Notice somewhat better air circulation opportunity in end-pile.)

type. Neither of these types are adapted to what might be termed final drying for musical instruments, furniture, high-grade cabinet work, interior trim, or any object where permanence of dimension and a high degree of finish are required.

The third type, which is often called "reversed" ventilation, has a downward circulation with outlets at the *bottom*. The fresh-air inlets are at or near the ceiling line and the damp-air exits are in the pit below the lumber. This method adapts itself most effectively to the handling of heavy moisture-laden air shown to be necessary to dry the lumber uniformly. Whenever any portion of the atmosphere of the kiln acquires a substantial amount of moisture, it will lose temperature, increase in weight, and settle. It is therefore necessary to provide an adequate damp-air accumulation pit below the lumber, and to supply chimneys or stacks with sufficient draft to carry this moisture-laden air up and out. Heavy air that has settled into a pit will not readily be drawn up a stack. Steam-heated pipes in the stacks will accomplish this and at the same time keep the water vapor from condensing on the interior of stacks or at their top outlets. This type gives opportunity for excellent control, as any humidity can be handled and the air discharge be under positive control under various climatic conditions. For high-grade work it affords reliable regulation of the three essentials: temperature, humidity, and circulation.

It has been the purpose of this paper to outline some of the fundamental principles in lumber drying and to indicate their most important applications. Many of the combinations of mechanical apparatus are adequately covered by United States and foreign patents, although the fundamental elements have been in use too long to have further protection.

(*Continued on page 120*)

Diesel-Engine Clutch Used in the German Submarine "U-117"

By W. H. Nicholson,[1] Camden, N. J.

The purpose of this paper is to give to American builders of Diesel engines the benefit of the author's knowledge of German Diesel-engine clutches obtained at the time of the dismantling of ex-German submarines in the United States. The U-117's clutch is described in detail and other types of German Diesel-engine clutches are covered generally.

The submarine *U-117* was commissioned by the Germans in 1917 and operated off our North Atlantic coast in that summer and in the summer of 1918. It is known that this submarine took part in the sinking of coal barges and fishing boats in the vicinity of Nantucket and it is supposed that she is responsible for the planting of mines off the Long Island Shore, one of which sank the U. S. Cruiser *San Diego*.[2]

The *U-117* is a large mine-laying and -operating submarine. Her overall dimensions are: length, 275 ft.; beam, 17 ft.; and draft, 10 ft. She has a carrying capacity of 20 torpedoes and 45 mines. The armament consists of a 6-in. rapid-fire gun forward

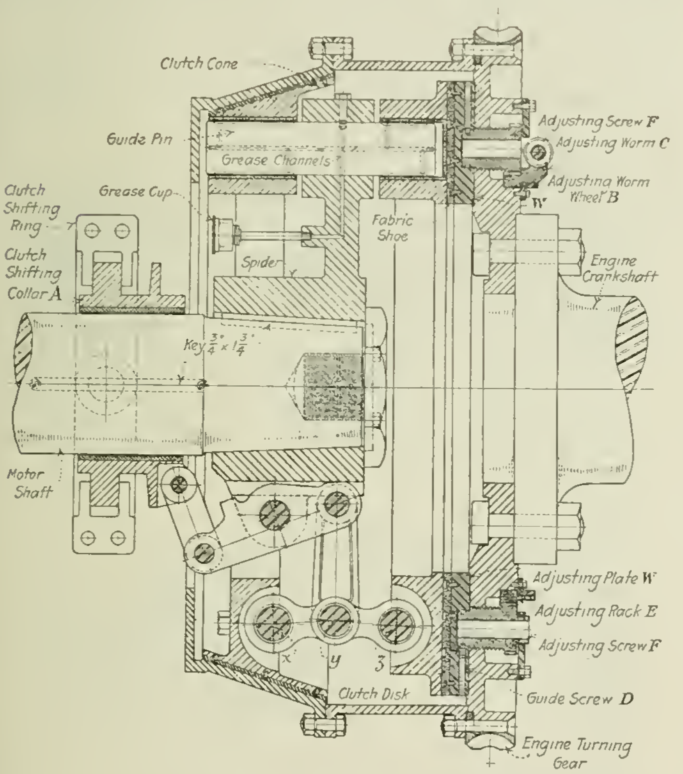


Fig. 1 Sectional View of Diesel-Engine Clutch Used in the German Submarine *U-117*

and a 5-in. gun aft, both on the main deck. There are four torpedo tubes in the compartment forward, and two mine tubes in the compartment aft.

The engine equipment consists of a port and a starboard Diesel oil engine, four-cycle, six-cylinder with two air-compressor cylinders of 1200 i.hp. at 450 r.p.m. for surface cruising and battery charging. The bore of the working cylinder is 17.73 in. and the stroke 16.5 in. The complete engines weigh 57,000 lb. each.

There are also the port and starboard main motors, each rated at 600 hp. at 332 r.p.m., for submerged operation. In general, the design of the motor comprises two compound interpole assemblies in one frame with the armatures in tandem on the same shaft motor-generator fashion. The motors receive their power from two 124-cell 248-volt storage batteries. When the boat is under way on the surface, each motor unit is driven as a generator by the Diesel oil engines, using the excess power of the engine to recharge the batteries and carry the auxiliary power load.

The log of the *U-117*, her general description, and the description of her propelling machinery give some idea of the work performed by her clutches.

Details of the *U-117* Main Engine Clutch

The clutch is located between the Diesel oil engine and the main

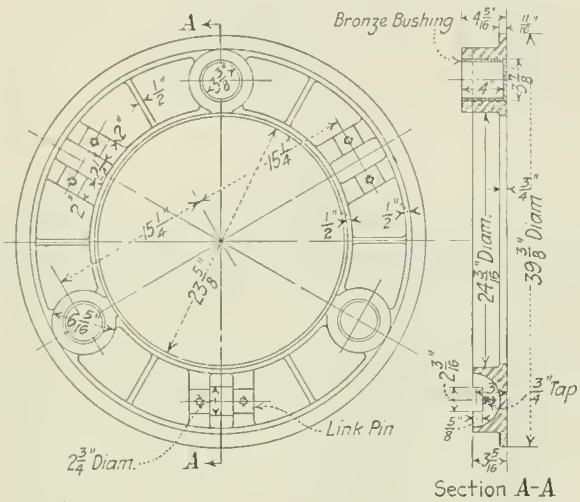


Fig. 2 Clutch Disk

motor, both port and starboard. It is of the single cone and disk friction dry type, constructed of semi-steel and cast iron, and operated by compressed air. The clutch was built to metric measure. All dimensions given in this paper, however, are in nearest inches or fractions of an inch.

The outer casing, adjusting plate, worm wheel, and adjusting screws, which serve as a flywheel, are carried on the engine crankshaft. The casing as shown in Fig. 1 is made of two parts bolted together. The inner surface of the after casing is machined to a cone surface; the forward casing is a straight sleeve or spacer for power transmission only. The extreme outside diameter of the casing is 45 in.

The inner clutch cone or male cone and clutch disk are carried on the guide pins of the spider, on which they are a sliding fit. They are of semi-steel and the outer surface of the male cone is finished to conform to the conical surface of the female or flywheel part. The forward surface of the clutch disk is finished for contact on the fabric shoe of the adjusting plate. Figs. 2 and 3 are detail sketches of the male cone and the clutch disk carried by the spider. The taper of the cone surfaces is about 14 deg. The cone and disk are bronze-bushed for the guide pins.

To the outer surface or periphery of the male cone there is attached, by means of countersunk machine screws, a fiber shoe as shown in Figs. 1 and 3. The shoe is $^1/_4$ in. thick and is made up in four sections, the divisions being in the direction of the axis of the guide pins or shaft. It is the surface of the fiber shoe that contacts with the metal surface of the female or outer casing when the clutch is thrown in.

The spider, attached to the motor shaft by a single key and a retaining screw has three guide pins parallel to the axis of the engine and motor shafts and extending through the spider on either side

[1] Designer, Engr. Dept., Westinghouse Elec. & Mfg. Co.

[2] The *U-117* was recently used as a target and sunk off the Virginia Capes in the U. S. Army airplane bombing experiments.

Contributed by the Gas Power Division for presentation at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. All papers are subject to revision.

as shown in Figs. 1 and 4. The guide pins are steel forgings and are shrunk in the spider.

The clutch is thrown in by forcing the male cone and the disk apart until the male and female cone surfaces engage and the disk surface engages the fabric shoe of the adjusting plate; and by drawing the male cone and the disk together and thus releasing the surfaces the clutch is thrown out. The male cone and the

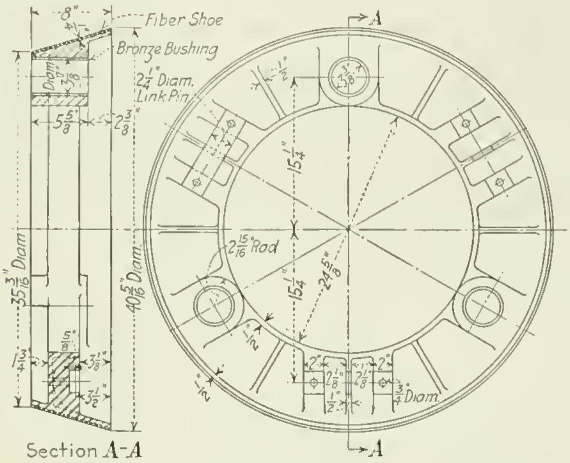


Fig. 3 Clutch Cone

disk are drawn together or forced apart by a series of links and toggles actuated by a sleeve or collar (A in Fig. 1) sliding on the motor shaft. The shifting collar is shown in detail in Fig. 5. It is babbitted for a sliding fit on the motor shaft and is single-keyed thereto.

Referring to the lower half of Fig. 1, the center x is shown fixed to the male cone and center z to the disk. The clutch is engaged by separating centers x and z and by forcing center y up to a line adjoining centers x and z. There are three sets of operating links and toggles equally spaced between guide pins of the spider as shown in Fig. 4.

To the after side of the worm wheel there is attached by means of six adjusting screws a steel disk or adjusting plate faced with fabric. The fabric is $^{7}/_{16}$ in. thick and serves the same purpose as the fiber shoe of the male cone. The fabric is also in four sections and is secured by means of countersunk machine screws. The sectional divisions of the fabric are radial. When the clutch is engaged, the forward surface or finished surface of the clutch disk has contact with the fabric shoe.

The fore-and-aft movement of the male cone and disk is $^{3}/_{8}$ in., or a total of $^{3}/_{4}$ in. The fiber and fabric shoes have some flexibility and it is these surfaces that absorb the load shocks and transmit the power of the engine. The design of this clutch differs in this respect from the clutch used with the 3000- and 1750-hp. engines, in that those clutches have, when engaged, a metal-to-metal contact on lubricated surfaces. The fabric and fiber shoes may be renewed when worn.

The adjusting worm wheel is carried on the engine turning gear (see B in Fig. 1) and is rotated by the adjusting worm (C) which is hand-operated from either end of the worm shaft by means of a wrench. The adjusting worm is bracketed to the engine turning-gear cover plate. Any movement of the adjusting worm is transmitted through the rack (E) and rotates the adjusting screws (F) which are threaded through the worm wheel. There are six adjusting screws equally spaced, three of which are secured to the adjusting plate by means of the guide screws (D). The other three adjusting screws have contact only on the forward surface of the adjusting plate; their ends are flat and do not penetrate the plate. The sketches do not show the short adjusting screws. By means of the adjusting mechanism there is a movement of $^{9}/_{16}$ in. between the disk and the fabric shoe, the adjusting plate moving aft from the turning gear that distance at the surfaces marked W in Fig. 1.

The guide pins of the spider are lubricated by means of three grease cups attached to its arms by a length of pipe. The guide pins and spider arms are drilled for the passage of grease and the former are grooved for its distribution. Plugs are inserted in the blind ends of drilled holes. The circumferential force of centrifugal force of the clutch should carry sufficient grease to the pins without attention to the grease cups except for occasional filling.

The clutch shifting cylinder shown in Fig. 6 is of semi-steel. The bore is 7 in. and the stroke is from $7^{1}/_{2}$ to 8 in., depending on the setting of the pistons. The pistons may be set for long or short stroke by means of the piston adjusting nuts. To prevent pistons from striking cylinder heads when operating, adjustable stops are provided on the guide rods and spring stops are secured to the cylinder heads. The springs at either end of the cylinder absorb the shocks when throwing the clutch in or out.

The general arrangement of the clutch is shown in Fig. 7. The clutch operating cylinder is placed alongside the engine with its center line parallel with the axis of the crankshaft.

The clutch cylinder is operated by air pressure and transmits its power through the crosshead, yoke, and fulcrum to the clutch.

The fulcrum bracket is of semi-steel and is carried on a foundation from the ship's floor. It is estimated that the load at the fulcrum is about 16,000 lb.

The clutch shifting ring is held in its position by the yoke pins and is lubricated for contact with the clutch shifting collar by means of a wick in the oil reservoir.

The engine-turning gear carried with the clutch consists of a worm wheel carried on the engine crankshaft flange and a hand-operated worm which is locked out of position when not in use. The diameter of the turning gear is $46^{3}/_{8}$ in., which is the extreme outside dimension of the assembled clutch.

Fig. 8 shows diagrammatically the arrangement of the clutch-shifting piping. Compressed air for the operation of the clutch

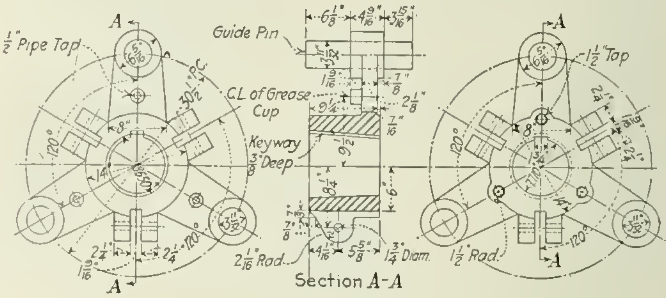


Fig. 4 Clutch Spider

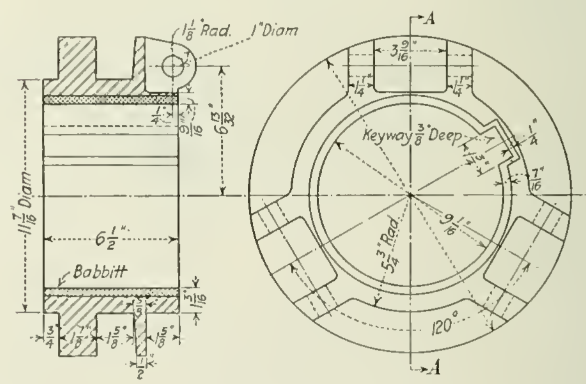


Fig. 5 Clutch Shifting Collar

is supplied from the main engine air-starting flasks at 160 atmospheres (metric measure) or about 2275 lb. per sq. in. It is noted that the air is drawn from the top of the flasks by means of an internal pipe to prevent water that may be collected in the flasks from passing through to the shifting cylinder and damaging it.

There is a pressure-regulating and relief valve in the pipe from the air-starting flasks, with stop valves on either side and at the flasks. The air passes through the clutch operating valve to the receivers and then to the clutch operating cylinder.

The clutch operating valve is so designed that its ports take care of the exhaust air from the opposite end of the clutch operating cylinder by a single movement of the handle, exhausting the air and entrained water to the ship's bilges.

When the clutch is thrown in, it is self-locking, as shown by position of links and toggles in lower half of Fig. 1. It is to be noted that this locking is accomplished by forcing center y slightly above centers x and z. Air may then be shut off from the clutch-shifting cylinder until it is necessary to throw the clutch out. The centrifugal force of the clutch will not throw it out. The advantage of the self-locking feature lies in the assurance that the holding power of the clutch does not depend on a constant pressure of air in the cylinder. Where air pressure would be used for holding the clutch in, there would be the possibility of leaks or fluctuations and the release of the clutch.

All air piping is $^1/_2$ in. in inside diameter and of seamless drawn steel with steel rings brazed to the ends for making up the joints. The pipes are secured in forged-steel fittings by means of a male nut placed on the pipe back of the brazed ring, the nuts then being screwed into the female joint of the fittings. Gaskets are either fiber or copper, placed within the fitting. All pipes and fittings tested to 3000 lb. hydrostatic pressure per sq. in.

For emergency there is a hand pump for the operation of the clutch.

Classification of German Diesel Engines and Clutches

The German Diesel oil engines were generally classified as follows:

- 10-cylinder, 4-cycle, 3000 i.hp., for large cruisers (submarine)
- 6-cylinder, 4-cycle, 1750 i.hp., for large operating submarines
- 6-cylinder, 4-cycle, 1200 i.hp., for large mine-laying and operating submarines
- 6-cylinder, 4-cycle, 550 i.hp., for mine-laying and coastal submarines.

Clutches for the 3000- and 1750-i.hp. engines were of the double-

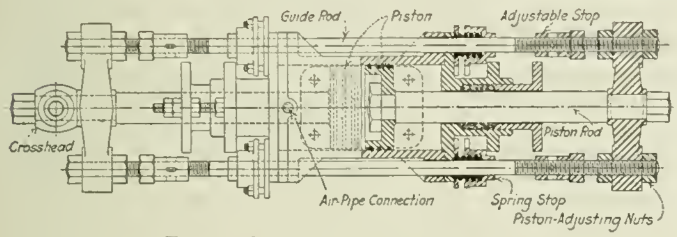


Fig. 6 Clutch Shifting Cylinder

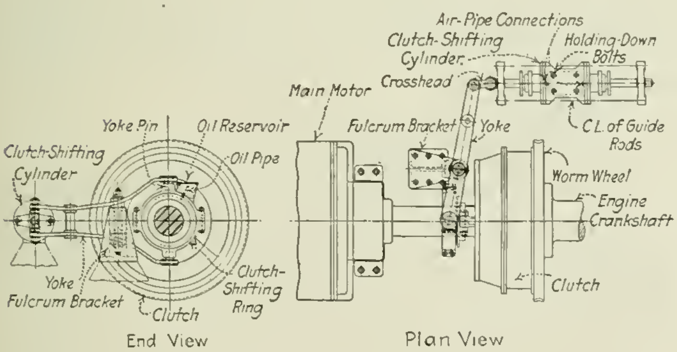


Fig. 7 General Arrangement of Clutch

cone, friction, lubricated type, operated by compressed air or electric motor.

Clutches for the 1200- and 550-i.hp. engines were of the single-cone and disk, friction, dry type. The 1200-i.hp. engine clutches were operated by air and are described in detail in this paper. The 550-i.hp. engine clutches were operated by hand through worm and gear.

The details of design of the German Diesel-engine clutches were practically unknown in this country prior to the surrender of the German submarines, and considerable difficulty was experienced in dismantling them.

At the time of the arrival of the submarine freighter *Deutschland* at New London, when an appointed board of naval officers and civilians inspected her to establish her status, it is known that much interest was shown in her clutches, the construction of which was considered remarkable in so far as so small a diameter of clutch was capable of transmitting such large horsepower. No information of value was then obtainable, but later, when the surrendered German submarines arrived in this country, the clutches were one of the first mechanisms to be investigated.

It is believed that many improvements can be made in the design of American clutches by adopting some of the principles of the German clutches. The author has had some experience with American clutches and has found them to be of the tooth or positive-drive type, or of the friction-jack type. These clutches have been

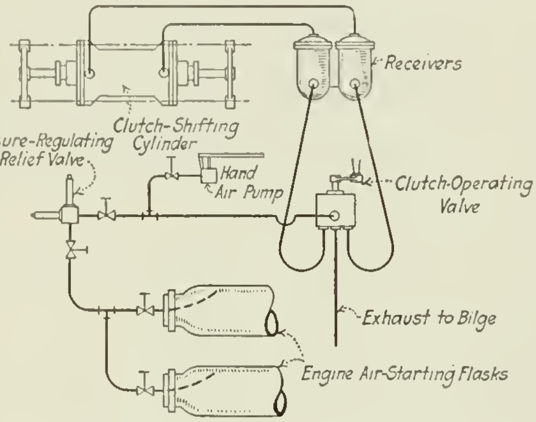


Fig. 8 Diagram Showing Arrangement of Clutch Shifting Piping

the source of trouble and are constantly in need of repair. The tooth type does not allow the flexibility of shaft speeds required in maneuvering a ship that a friction type allows, and from experience it has been found that the friction types are not of sufficient strength and rigidity to transmit heavy loads. During the war one of our American submarines went below her depth by accident and it was necessary to insert emery paper in the clutch before the jaws would take hold and allow her motors to operate the shaft-driven bilge pump. Such delays may cause the loss of a ship and many lives.

The friction-jack types are usually thrown in by hand through a series of levers and therefore lack the holding power of an air-operated clutch.

With the friction-jack type of clutch there is nearly always a misalignment of shafts when the clutch is in, due to improper setting of the jack screws or adjusting screws. The screws are placed radially and must be adjusted from time to time to take up wear. It requires a skilled operator to properly adjust such a clutch.

In the German clutches the adjustment is fore and aft along the axis of the shaft, and with a proper alignment of shafts when machinery is first installed there is little possibility of misalignment when the clutch is in.

The author will be glad to give any further information desired by clutch manufacturers or engineers that will help to improve our American clutches.

During the past year there has been a marked drift toward larger units of Diesel engines. Only a few years ago the Diesel engine was confined to sizes under 500 hp. It was considered that 150 hp. per cylinder was the maximum to be obtained save at the sacrifice of reliability. This impression has been obliberated, and a number of manufacturers are building units of 300 to 400 hp. per cylinder. Two years ago an investigation by *Power* on the Diesel engine industry revealed that the average horsepower per engine was close to 300. In 1922 the average horsepower per engine sold was over 500 and the total horsepower approximately 70,000. This is evidence of the greater faith of the builder as well as the increased confidence of the power user in the internal-combustion engine. A marked activity has been shown in the development of solid-ignition, gas-injection, and other oil engines not using air compressors. These units have been of such sizes as to be competitors of the semi-Diesel rather than of the Diesel engine. It would seem that these types will find their logical place between the capacities that are naturally Diesel and those adaptable to the semi-Diesel. *Power*, January 2, 1923, p. 17.

Test Code on Instruments and Apparatus

Preliminary Draft of Chapters 1 and 2, Dealing Respectively with General Considerations and with the Accuracy of Measuring Instruments, and Being the First Installment of this A.S.M.E. Power Test Code to be Published

As STATED a number of times before, the A.S.M.E. Committee on Power Test Codes is now engaged in the revision of the Society's Power Test Codes of 1915. Mr. Fred R. Low is Chairman of the Main Committee of twenty-five which guides the work of the nineteen Individual Committees. Below are reproduced the first two chapters of the Code on Instruments and Apparatus which is to cover the descriptions of instruments, apparatus, and processes common to the sixteen Power Test Codes. The individual Committee which is developing this Code is headed by Mr. C. F. Hirshfeld as Chairman and consists of Messrs. C. M. Allen, E. G. Bailey, L. J. Briggs, W. A. Carter, R. E. Dillon, S. B. Flagg, S. A. Moss, R. J. S. Pigott, G. B. Upton, E. B. Ricketts, J. J. Flather, F. M. Farmer and J. B. Grumbein.

The Committee and the Society will welcome suggestions for corrections or additions to these two chapters from those who are particularly interested in this part of the subject. These comments should be addressed to the Chairman of the Committee in care of The American Society of Mechanical Engineers.

CHAPTER I

General Considerations

1 The instruments and apparatus here considered are those used for measuring physical and chemical quantities in connection with tests of power equipment of various sorts, as required by other parts of the Code.

2 Measurement of a physical quantity never gives a result which is correct in an absolute sense. The numerical value determined always differs by some amount from the real value being measured, and the extent of the deviation depends upon the type of instrument and the method of its application. This fact imposes upon testing engineers the duty of studying measuring instruments and methods to such an extent that they can show in any given case that they have made all measurements to the degree of accuracy demanded by the purpose of the test.

3 The *accuracy* attainable in any given measurement is dependent upon four things:

- (*a*) The method of applying the instrument
- (*b*) The accuracy of the instrument itself
- (*c*) The accuracy of the observer, and
- (*d*) The characteristics of the quantity being measured.

4 As examples of the first effect the following may be cited:

(*a*) Even if a steam calorimeter were capable of indicating the quality of steam flowing through it without error of any sort and if the observer handled it perfectly, the value determined in any given case would not be the quality of steam in the pipe unless the sample flowing through the calorimeter correctly represented the steam flowing through the pipe from which the sample was drawn.

(*b*) If an absolutely accurate thermometer and a perfect observer could be obtained, such thermometer and observer would not necessarily give correct results in the measurement of, say, the temperature of superheated steam, unless the thermometer was properly immersed in the superheated steam or in a body having the same temperature as that steam and all necessary precautions were taken with regard to the thermal condition of the part of the thermometer not immersed.

(*c*) If a steam-engine indicator was a perfect instrument and perfect observers were obtainable, the card given by the indicator would still be in error if the pressure connections were not such as to apply instantaneously to the indicator piston the pressure acting on the engine piston, or if the motion of the indicator drum did not perfectly follow the motion of the engine piston.

5 In connection with the accuracy of the instrument, it should be noted that no instrument is accurate in an absolute sense. All instruments give only a more or less close approximation to the value of the quantity being measured. It is necessary to use that type which will measure to the required degree of accuracy and to know that it is in condition to do so. The accuracy of instruments will be considered at length in later paragraphs.

6 Accuracy of observers is not commonly given the attention it deserves. An observer should always be familiar with the theory and the mechanism of the instrument which he is using and should understand the degree of accuracy required on his part in its use. However, even after all such precautions have been taken there are still two forms of observational error to be guarded against. These are:

- (*a*) Accidental errors, due to misreading the graduations, incorrect entry on the log of a value correctly read, failure to perform some necessary manipulation, etc.; and—
- (*b*) Personal errors which are dependent upon the personal equation of the observer, such as carelessness in interpolation, tendency to consistently read high or low, inability to read rapidly, thus introducing a time lag, etc.

7 The characteristics of the measurement being made are of particular significance in engineering testing because conditions must usually be accepted as found. In the laboratory, on the other hand, conditions are ordinarily altered to facilitate measurement. Thus a quantity the magnitude of which is continuously changing is more difficult to measure at any moment than when it is not changing. The more rapid the variation the greater the difficulty, and, in general, the lower the accuracy attainable. Again, some quantities are measured so often under similar conditions that the methods have been developed in great detail, while others are measured so seldom or are ordinarily measured under such different conditions that little is known with respect to details, best methods, sources of error, etc.

8 At best, there will always be required in engineering tests certain measurements which are of such character that the degree of accuracy obtainable will be questionable. As examples of measurements which fall into this class at the present time the following may be cited:

- (*a*) Determination of steam quality
- (*b*) Determination of the temperature of superheated steam
- (*c*) Determination of the calorific value of fuels
- (*d*) Determination of combustible in boiler refuse, etc.

Since it is the purpose of the Code to provide methods upon which all can agree and upon the basis of which business can be done and guarantees can be made, rather than to produce a set of directions for scientific investigations, such cases are hereafter handled in a purely arbitrary manner. That is, attention is called to the known sources of error and to those precautions which can be taken to minimize their effects, and an arbitrary standard method of measurement is then prescribed. It is anticipated that as research develops, more accurate methods than these will be prescribed in subsequent revisions of the Code.

CHAPTER II

Accuracy of Measuring Instruments

1 Attention has been called to the fact that instrumental accuracy is purely a relative matter; there is no such thing as absolute accuracy in connection with the measurement of physical quantities. Accuracy in this connection has to do with two radically different considerations which may be designated as—

- (*a*) The *intrinsic accuracy* of the instrument, and
- (*b*) The *accuracy* resulting under the *conditions of use.*

The former is treated generally in the paragraphs which follow and more specifically in later sections dealing with individual instruments. The effects of conditions of use are considered in the sections dealing with the individual instruments.

2 *Accuracy* is used to designate the extent to which the indications of an instrument approach true values of the quantity being measured. The accuracy of an instrument can be determined by calibration, but it is important to note that this often determines the accuracy only for conditions of use similar to those maintained during calibration. For this reason it is often advisable to calibrate by methods which will subject the instrument to as nearly as possible the same conditions as those existing during use in a given test. It is also important to note that moving an instrument to or from the place of use or that dismantling during installation or removal may seriously affect its accuracy. For this reason calibration in place may be necessary under some conditions or with some types of equipment.

3 The methods used for expressing accuracy vary. One common method is to state that the instrument is accurate to within plus or minus a certain specific amount or a certain percentage at a certain point on the scale or between certain points on the scale. Thus a thermometer may be described as having an error not in excess of -0.5 deg. fahr. between 100 deg. fahr. and 300 deg. fahr. It is convenient to state the accuracy of instruments in this way when speaking in a general sense, but other methods are preferable for more specific applications. For such purposes the form of expression should indicate the correction to be added to the indication of the instrument to obtain the real value of the measured quantity. Thus, a thermometer might be said to have a correction of $+0.5$ deg., indicating that at this point of the scale it reads 0.5 too low. A correction of -0.5 would mean that it reads 0.5 too high.

4 For comparison of various instruments of similar character among themselves the specific inaccuracy at normal indications is a most useful value. The specific inaccuracy is the ratio of error to true value. The numerical value may be the same or different for various points within the range of the instrument. As an example of the meaning of this term, assume a pressure gage which reads 48 lb. when a pressure of 50 lb. is applied and 98 lb. when 100 lb. is applied. The specific inaccuracy at the lower point is $2/50 = 0.04$ or 4 per cent, and at the higher point $2/100 = 0.02$ or 2 per cent. If the inaccuracy is specified as a certain percentage of the full scale reading, then the maximum inaccuracy at any other reading is inversely proportional to that reading. This sort of thing is characteristic of nearly all measuring instruments which carry a uniform scale, that is, a scale divided uniformly from end to end. An error of given magnitude at a high scale reading represents a much smaller percentage error or specific inaccuracy than does an error of the same magnitude at a low scale reading. When instruments are so arranged that the length on the scale representing one unit of the measured quantity is long at the center of the scale and short at each end, the specific inaccuracy must obviously vary throughout the entire range in a more complicated way. Smaller inaccuracy in observation will be obtained with an instrument having two or more ranges than with one having only one range, as the deflection of the pointer or index to a point of maximum amplitude will reduce to a minimum errors due to parallax in observation or to any other cause.

5 *Inaccuracy* of an instrument in the sense in which it is here used is caused by features or factors in the instrument itself and has nothing to do with the effect of external conditions other than the value of the quantity being measured. Inaccuracy may be due to great number of different causes acting singly or in combination. The principal causes are:

(*a*) *Imperfect material,* as variation in bore of a glass tube, variation in the molecular structure of the material of springs, etc.

(*b*) *Unavoidable physical phenomena* such as capillary attraction, imperfect refraction of light, friction of rest and motion, etc.

(*c*) *Imperfect construction* which *cannot be improved,* such as lost motion in gear trains resulting from necessary clearance in bearings or between teeth, changing lengths of levers due to necessary clearance in bearings or to the finite width of knife edges or points, etc.

(*d*) *Imperfect construction* which *can be improved,* such as excessive friction, excessive lost motion, incorrectly cut cams, etc.

(*e*) Unavoidable or partly unavoidable *properties of materials* such as the aging of glass, the gradual yielding of materials to physical stress, the aging of permanent magnets, etc.

6 Inaccuracies arising from such causes as are included under Par. 5 (*a*) are ordinarily of irregular character, causing more or less erratic errors throughout the range of the instrument. They are usually permanent in character or change but slowly and are easily taken into account during calibration.

7 Inaccuracies arising from such causes as are included under Par. 5 (*b*), (*c*) and (*d*) are more or less regular in character and are responsible for what has been called the hysteresis loop of an instrument. This is the loop which is obtained by plotting instrument readings against true values, using the instrument first in an ascending sense and then in a descending sense. A similar but different loop can be obtained by plotting errors against true values or corrections against indicated values. This is considered later in greater detail.

8 Inaccuracies arising from causes included under Par. 5 (*c*) are responsible for what is known as aging or drift in instruments. Within certain limits such aging or drift is not detrimental, although it does necessitate frequent calibration to guard against its effects. In certain cases it must be taken into account if erratic results are to be avoided. Thus a glass thermometer which is to be subjected to high temperatures must be artificially aged before calibration and use.

9 *Sluggishness* is a term used to indicate the amount of displacing or actuating effect required to cause motion of the indicating part of an instrument. It is determined by noting the smallest alteration in the quantity being measured that will produce a perceptible change in the indication of the instrument. Thus a thermometer which at 400 deg. fahr. requires a change of ± 5 deg. fahr. to cause it to move up or down will have a sluggishness index of $5/400 = 0.0125$. This factor is most useful when expressed as a percentage, giving 1.25 per cent in the example cited. In comparing the sluggishness-index factors of instruments calibrated in different units it is necessary to refer them to the same base. Thus a thermometer calibrated in degrees centigrade would have the same factor as the one just considered if it required a change of ± 2.78 deg. cent. ($= 5/1.8$) to cause it to move up or down, since the temperature of 400 deg. fahr. corresponds with 204.4 deg. cent. or 222.2 deg. cent. above 0 deg. fahr. (-17.8 deg. cent.) which is the base of the fahrenheit scale. The sluggishness factor in this case would be $2.78/222.2 = 0.0125$ or 1.25 per cent. The value of the factor may and probably will be different for all points within the range of the instrument. "Passiveness" is often used as synonymous with sluggishness.

10 Sluggishness is often thought of as the opposite of sensitiveness or sensibility. Thus it is common to speak of a thermometer as "sensitive to 0.1 deg. fahr." meaning that it will respond to changes of that magnitude. This is technically an incorrect usage. Sensitivity is defined as the rate of displacement of the indicating element of the instrument per unit change of the measured quantity. That one of a group of comparable instruments which gives the greatest displacement for a given change in the measured quantity is the most sensitive.

11 *Sensitivity* of instruments is a most important property, as with other things equal it is the thing which determines the degree of refinement possible in their use. Unfortunately instruments are not always designed and constructed in such a way that the total available sensitivity is useful. Thus an instrument may be so constructed that it is possible to read on its indicator the movement corresponding to a variation of one unit in the value of the quantity being measured, but it may be so built that it will indicate values varying by as much as five units in successive trials with no change in the actual value being measured. The sensitivity of such an instrument is partly useless and is really misleading. A correctly designed instrument should have such sensitivity that the minimum readable movement of its indicator is not less than the amount by which the instrument may be expected to vary in successive indications of the same value of the measured quantity. To be exact these requirements should be stated in terms of the mean for both indication and variation as both may vary from point to point throughout the range of the instrument.

12 Sensitivity in excess of requirements, as set by the accuracy

desired in a given set of measurements, is generally a detriment because it involves delicacy, slowness of operation, or some other undesirable quality.

13 *Variance* is a term used to represent the amount by which the readings of an instrument vary in successive indications of the same value of the measured quantity. Variance is due principally to—

(*a*) *Lost motion*, which also affects the sluggishness or passiveness;
(*b*) *Friction*, which also affects the sluggishness or passiveness;
(*c*) Changes due to the stress-strain relation of springs *in the force-resisting or restoring element* of the instrument;
(*d*) *Changes in the distribution of parts*, as variation of position of pins in bearings or variation in the amount of liquid retained on wetted surfaces
(*e*) The *immediately preceding history* with respect to extent and speed of displacement; and—
(*f*) A great number of other more or less obscure phenomena.

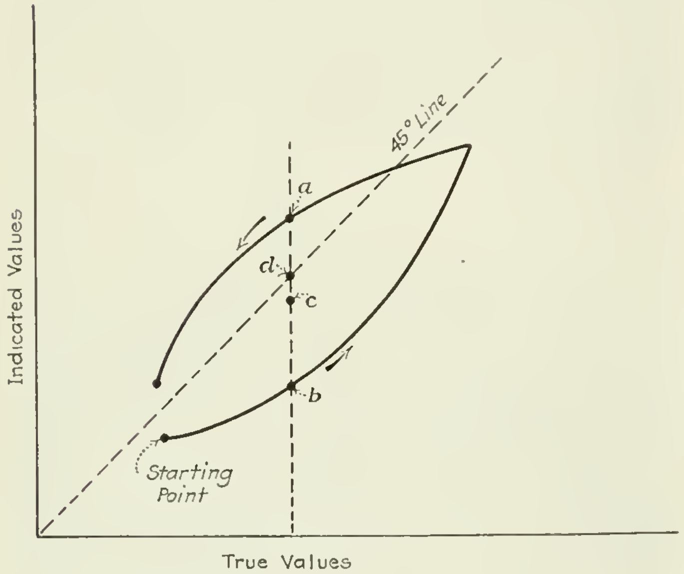


Fig. 1

14 Variance due to lost motion is commonly associated with the direction of motion of the parts in the instrument and it could be almost entirely eliminated if a given value could always be approached from the same side. Under conditions of use this is commonly impossible, although it can be done during calibration if desired.

15 Variance due to friction can be partly eliminated by tapping the instrument just before taking a reading. This is common practice in the use of instruments containing mechanical movements and is recommended if not carried to excess.

16 Variance due to the other causes enumerated above is not under control except in so far as it can be kept at a minimum value by proper maintenance and proper handling.

17 Instruments which are used in tests made according to the A.S.M.E. Power Test Codes must be tested to such an extent as may be necessary to determine their condition and their accuracy. Such testing is commonly known as *calibration of the instrument*.

18 The exact procedure to be followed in calibrating instruments varies not only with the instrument but also with the use to which it is to be put, the accuracy desired and other considerations. In general the calibration should include determination of the following throughout the range which is to be used:

(*a*) Sluggishness and its relation to the sensitivity of the instrument
(*b*) Variance and its relation to the sensitivity of the instrument
(*c*) Accuracy, or error of indication at different points within the useful range.

19 The principal methods available for the calibration of instruments and apparatus of different sorts are treated in detail in later paragraphs when the individual instruments are considered. Certain general features more or less applicable to all instruments are, however, discussed in the following paragraphs.

20 Calibration for the determination of error of indication may be conducted with one of two different objects in view: It may be desired to determine the errors of indication with respect to absolute accuracy; or it may be desired to determine only the extent to which the instrument is constant within itself with no reference to absolute values. As an example of the latter case, consider a speed-measuring device used in connection with a test to determine governor regulation with change of load. Under such conditions it is essential that the instrument shall give properly comparable values, but a correct indication of any one speed is not essential. In most cases, however, calibration on an absolute basis is required.

21 Most *calibrations* for error of indication are made by direct *comparison* of the readings of the instrument under calibration with the readings of some other instrument which is used as a standard, or by subjecting the instrument to the action of effects of known magnitude. Thus a thermometer may be calibrated by comparing its indications with those of another thermometer previously calibrated, with the two immersed in a liquid under such conditions that they should indicate the same temperature. Or, a thermometer may be calibrated by immersing it in pure materials undergoing changes of physical state known to occur at certain definite temperatures.

22 When it can be done, it is best to calibrate by some method which will make it possible to determine the errors of the instrument at successive points on its scale while the quantity being measured is varied by steps in an ascending and in a descending sense, successively.

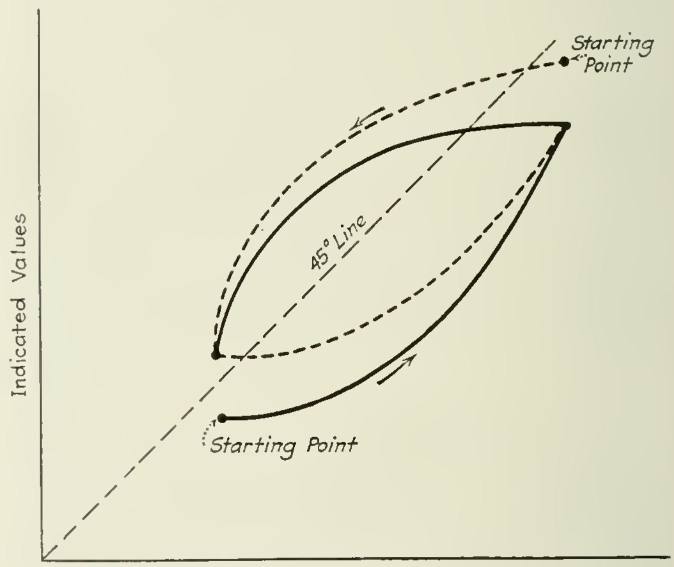


Fig. 2

23 When indications obtained in this way are plotted against true values a *hysteresis loop* will generally result if the work is done with sufficient care and skill. Such a loop is shown in Fig. 1 for a case in which ascending values are determined first and in which the instrument was reading a lower value than that at the starting point before calibration started. In such a case the lower end of the loop will not commonly close. If the procedure is reversed so that calibration starts at the higher values the resultant curve will be reversed in shape and the upper end will not close in most cases.

24 An ideally perfect instrument absolutely accurate throughout the range under test will give results plotting on the 45-deg. line indicated in Fig. 1 if true values and indicated values are plotted to the same scale.

25 In Fig. 2 are shown two hysteresis loops which might be obtained when calibrating the same instrument. The loop shown in full lines would be obtained with ascending values determined

first and that shown in dotted lines with descending values determined first. Obviously there is no simple correction for such an instrument. The departure from the true value varies with the past history of its moving parts or elements. It is also important to note that successive trials may not give values which will plot on the same hysteresis loops, particularly if the steps used in successive trials are of radically different magnitudes, or the rates of variation are radically different or the amount of vibration to which the instrument is subjected differs.

26 For convenience in engineering tests it is customary to draw some single line or curve as a sort of average of the hysteresis loop and to use this as the "calibration curve" of the instrument. This line or curve is usually drawn by plotting a series of points, each one of which is the mean of figures obtained for corresponding true values when ascending and descending. This procedure is shown in Fig. 3 for the case in which only one hysteresis loop is determined. It is obvious that the exact shape and location of such a curve will vary with the way in which the loop is obtained. It follows that the "calibration curve" is not a true representation of the behavior of the instrument during its calibration, and, further, that it is not an exact means for correction of indications obtained under the constantly varying conditions of use. The approximate nature of the calibration curve should be kept in mind in all considerations dealing with the accuracy of observations and hence with the accuracy of test results.

27 It is obvious that, with other things equal, the most accurate results are to be expected with instruments giving the narrowest

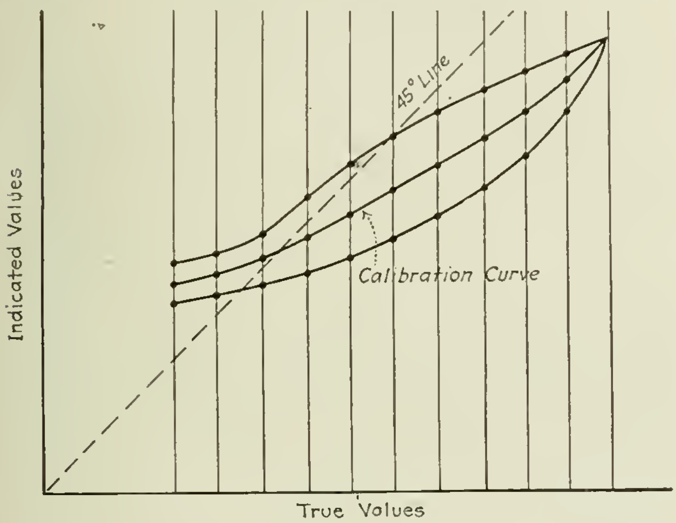


Fig. 3

hysteresis loops, and such instruments should be used when obtainable and when their use is justified by the degree of accuracy desired in the test.

28 The calibration curve as shown in Fig. 3 is not in the most convenient form for use under ordinary conditions. It is better to put it in the form shown in Fig. 4. Drawn in this way it is easily used and there is little possibility for error in its use. It has the further advantage that for ordinary conditions the entire plot occupies very little space, so that a number of curves can be drawn on one sheet without danger of causing confusion. Such an arrangement is shown in Fig. 5.

29 It will be observed that the calibration curve obtained in the way indicated shows only the average amounts by which the indications of the instrument may be expected to vary from the true values of the measured quantity. Such a curve tells nothing about sluggishness, sensitivity, or variance. These characteristics are, however, of importance in most cases and should be investigated during the calibration for the purpose of determining the adaptability of the instrument to the use intended, its condition, and the accuracy which can be obtained in its use.

30 *Sluggishness* is best investigated by determining the amount of displacing effect required to start useful motion of the indicating element after the instrument has been at rest. Such determinations should be made throughout the range which it is intended to use. In most cases such tests can be made conveniently while obtaining data for the hysteresis loop, so that a separate calibration for determining sluggishness is not commonly necessary. The observations made in determining sluggishness should be recorded with the other calibration data. They are best converted to a sluggishness index for successive points in the scale and tabulated as such.

31 The *sluggishness index* is not an exact numerical value in an absolute sense. The amount of vibration to which an instrument is subjected during calibration or use has a marked influence on its performance in this respect. Vibration has a tendency to decrease

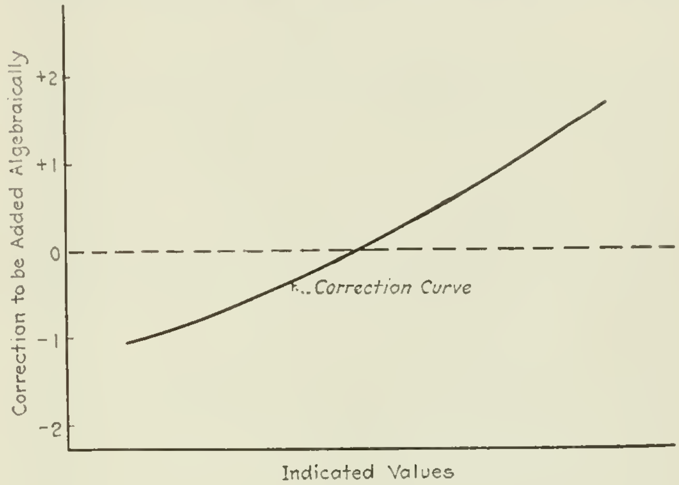


Fig. 4

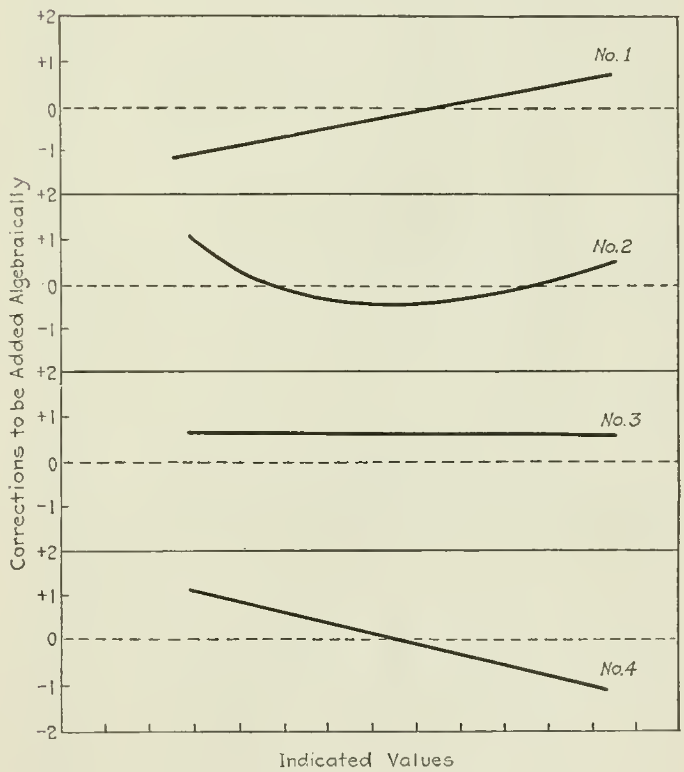


Fig. 5

sluggishness in all instruments containing kinematic trains of any sort, pivots, bearings, and the like. For this reason it is customary to tap such instruments to induce vibration before reading. This should be taken into account during calibration, both in determining the error of the instrument and in determining the sluggishness factor. If an instrument is going to be used under such conditions that it will be subjected to vibration or can be tapped before reading, it should be calibrated under analogous conditions. Again, the rate of variation of the measured quantity has a marked effect on sluggishness. The sluggishness factor determined when the variation of the measured quantity is very slow and very steady will be, ordinarily, quite different from that determined when the variation

is rapid but steady and, further, quite different from that determined with rapid variations of opposite sign. All these factors should be taken into account when calibrating, an effort being made to approximate as nearly as possible the conditions to which the instrument will be subjected when in use.

32 *Variance* can be determined directly from a hysteresis loop or, better, from a number of hysteresis loops obtained by starting at different points and by subjecting the instrument to variations of different directions, intensities, etc. The points marked *a* and *b* in Fig. 1 show two radically different indications which might be obtained for the same value of the measured quantity. It is quite common to assume that a point *c* midway between points *a* and *b* indicates the reading that would be obtained were there no variance. This is consistent with Par. 26. With this assumption the distance between *a* and *c* is a measure of the variance of the instrument at this particular point in the scale. There is obviously no certainty that the instrument will ever read closer to *c* than is indicated by the points *a* and *b*, respectively, and the possibility of variance of such extent must always be assumed in testing. Naturally, the value of variance will vary from point to point, so that it should be determined throughout the range that is to be used. When variance is determined in this way it should be tabulated or plotted and the record preserved with other calibration records of the instrument.

33 *Variance*, like sluggishness, varies in value with the conditions existing during test or use. The character of the variation of the value of the quantity being measured the amount of vibration and other factors all have their influence. As an example, consider an instrument subjected to a sudden increase of actuating force or effect of sufficient magnitude to cause its indicating parts to move so rapidly that inertia carries them beyond the position they would normally assume, for the final value of the quantity being measured. It may be that the amount of overtravel is so great that the unbalanced forces resulting are more than sufficient to overcome sluggishness without any vibration of the instrument. It may be that the overtravel is not so great and that sluggishness prevents restoration to the proper position even with vibration. It may be that the lost motion in the mechanical train is so great that even though the essential moving part of the mechanism comes back to a correct position the indicator or pointer remains in the position of overtravel. There are so many possibilities that it is practically impossible to correct for variance in the actual use of many instruments. The best that can be done is to recognize the fact that the calibration curve of the instrument is in reality not a line but a band of finite width (or height) and to interpret its readings and test results depending on those readings in the light of such knowledge.

34 *Sensitivity* is a property determined by the design of the instrument; it does not change with the condition of the instrument. In case of mechanically operated instruments if a certain moving element has been chosen and a certain multiplying device has been designed, the pointer or other indicator must theoretically move a certain distance for a given change in the value of the quantity being measured. In the case of a device like a mercury thermometer, if a given amount of mercury is subjected to a given change in temperature a certain volume change must occur and, in a capillary tube of a given bore, this must cause a movement of a given amount. The numerical value of the sensitivity is thus a characteristic determined by the design of the instrument. It is significant primarily in making a choice of instruments. These must have such sensitivity that the values of the quantities being measured can be read upon the instrument to at least as small a subdivision as is required by the conditions of the test.

35 The value of the sensitivity can be determined readily from the results of the calibration by noting the amount of displacement occurring for given variations in the values of the quantity being measured. It then becomes possible to state the displacement per unit of value and the minimum readable variation which follows from the design of the instrument.

36 It is always necessary to compare the values of sensitivity thus determined with the value determined for sluggishness and variance. Sensitivity within the limits set by sluggishness and variance is useless, and an attempt to use it results only in wasted effort and, possibly, mistaken accuracy.

LUMBER DRY KILNS

(*Continued from page 112*)

A few standards of construction, design, and operating methods are given below for the purpose of assisting in general layouts and development sketches.

Kilns may be *end-pile* or *cross-pile*, i.e., boards may be parallel or at right angles to the rails (Fig. 4), depending largely on the factory and yard arrangements. End-pile gives slightly better internal circulation, although this is rarely determinative.

A kiln car of lumber is usually 6 ft. wide, 9 ft. high (above rails including trucks), and from 12 to 16 ft. long (rarely longer). Higher loads not only upset easily but greater heights introduce uneven drying, or wet pockets, because of unavoidable temperature differences between the bottom and top of an enclosed space. The writer knows of a battery of kilns 20 ft. high in which the top half of the load always dried first and there was a temptation to discharge the kiln before the bottom half dried.

Kilns may be of the *progressive* (open at both ends) or *single charge* (usually open one end) type as shown in Fig. 5. The former

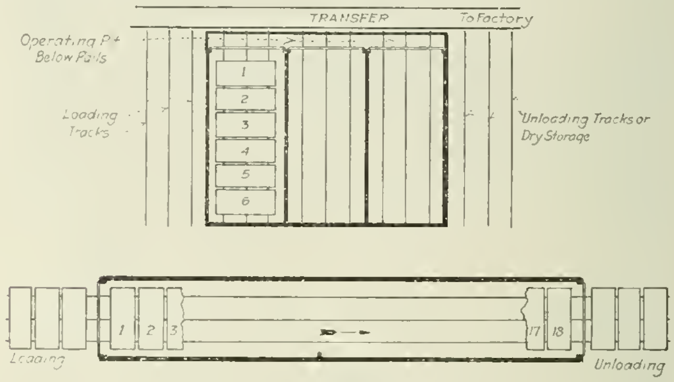


Fig. 5 Progressive Kiln (Below) and Single Charge (Above)
(Each has equal holding capacity and output, together with minimum necessary trackage for loading and unloading.)

involves a daily opening to remove and enter lumber, a daily moving forward of every car, with a consequent loss of from 5 to 10 per cent of the drying period from the opening of kiln, during the time required to cool sufficiently to move the cars, to the time when temperature and humidity are restored to operative conditions. The progressive kiln, to be efficient, requires that the charging end be maintained at a low temperature and a high humidity and the discharging end at a high temperature and low humidity with graduated intermediated conditions. Air circulation, chiefly transverse, prevents dependable graduated conditions and the operator copes with irregular conditions. The subdivision of the heat and humidity sources may be of slight help, but in any case the progressive kiln is more complicated than the single-charge type.

The latter type (sometimes called box, compartment, pocket, or cell) requires the operator to vary his entire kiln regulation from day to day according to a predetermined schedule. The room is small enough so that control of uniform conditions throughout is simple. Various kinds and thicknesses of lumber can be separated in different rooms and given individual treatment. Valves and dampers can be located in an accessible outside pit. When built in batteries with adequate transfer and yard trackage the single-charge type will produce as great a turnover from the investment as the progressive, and dry the lumber better.

Hollow tile, with an exterior brick veneer, makes the best walls, and a tile and reinforced-concrete roof with insulated wooden doors will complete an economical heat-retaining building. Solid concrete is not only a poor insulator but adsorbs too much moisture and checks badly under high temperatures. Frame buildings, under the varying conditions of temperature and humidity, rot and rack rapidly.

Scientific kiln drying is only at its beginning and wood users have but commenced to visualize the efficiency and economy that is possible. Engineers can do much toward the solution of the problem by giving it the same degree of study and research that has resulted in substantial progress in other fields.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AERONAUTICS (See also Internal-Combustion Engineering)

British Air Ministry and Rateau Scheme for High Flying. It is stated that the Directorate of Research of the Air Ministry (British) has rejected the Rateau scheme for flight at high altitudes for the following reasons quoted from the letter of the Directorate.

"Considering the conditions under which both turbine and blower have to work, it is not considered possible to obtain overall efficiencies of the order of 30 per cent. A more likely value would be 20 per cent, with 25 per cent as a practical limit. Taking 22.5 per cent as a value for an average plant, back pressures of the order of 3 lb. per sq. in. will have to be allowed in order to restore ground-level inlet pressures at 15,000 ft. The utility of the device will then depend largely on the effect this back pressure has on the running of an engine. In this connection both loss in power and possible overheating will have to be considered. In any case, the strictly limited range of 'full compensation' shows that the scheme proposed by Professor Rateau is not a complete solution of the problem, and that at greater altitudes, especially, other schemes will have to be considered." (*The Practical Engineer*, vol. 66, no. 1867, Dec. 7, 1922, pp. 353–354, *g*.—The mathematical foundations for the high-altitude flight scheme of Professor Rateau, Mem. Am.Soc.M.E., were presented in his paper before the Society and published in Mechanical Engineering, May, 1920.)

Paragon Adjustable and Reversible Propeller. Description of a propeller recently tested at Bolling Field. For this purpose it was installed on an automobile truck trailer equipped with a 150-hp. Wright-Hispano engine.

The two wooden or steel blades are fastened into steel sleeves, which, in turn, are held in a steel hub, the centrifugal force being taken on ball thrusts and torsional and axial forces on plain bearings. In the method of fixing the wooden blades into the steel sleeves as illustrated in the original article, the butt end of each blade is tapered outwardly at a small angle and the surrounding collar is split so that it may be first sprung over the butt and then compressed into the taper.

The pitch-changing mechanism is operated through the application of a braking force to either one of a pair of small brake drums surrounding the engine crankshaft and normally rotating with it. The brake drums are connected through a gear train to the individual blades of the propeller.

In the tests the engine was turning at 1500 r.p.m. No data are given as to the strength of the blade where it is held by the split collar and as to its ability to resist the centrifugal stresses, which is the main problem in the design of a variable-pitch propeller. (*Aerial Age*, vol. 15, no. 21, Dec., 1922, pp. 587–589, *d*)

Four-Engine All-Metal Airplane Built by the Schneider Co. Description of a airplane of the Henri-Paul type built by the great Schneider Works, the largest steel plant in France. There are several reasons why this airplane becomes of considerable interest.

The machine is of very considerable dimensions, weighing with full flying kit 10,020 kg. (22,050 lb.). It is equipped with four Lorraine-Diétrich motors of 370 to 400 hp. each.

The wings are made with chrome-nickel steel frame members with stiffening ribs of a light alloy. The fuselage is made up of high-resistance light alloy and steel tubing.

The original article gives considerable attention to the aerodynamic properties of the machine and some data on design. It is also stated that the Schneider works have under construction two four-engine airplanes which are each equipped with a 75-mm. gun. (*Le Génie Civil*, vol. 81, no. 23, Dec. 2, 1922, pp. 505–510, 18 figs., *dA*)

ELECTRICAL ENGINEERING (See Power-Plant Engineering)

ENGINEERING MATERIALS

Lead-Coated Pipe in the A. T. & S. F. Railway Enginehouses. Considerable trouble has been experienced from rapid deterioration of water pipe in enginehouses on the A. T. & S. F. Railway, and in an effort to remedy the situation a process of lead plating of pipe has been developed.

This is done in the following way: The material to be plated is first cleaned by immersion in a lye vat which serves to remove the grease and oil. The surfaces are next washed with a jet of water and then placed in another vat filled with a 17 per cent solution of sulphuric acid, which is followed by scouring produced by adding about 15 lb. of Chile saltpeter for each 600 sq. ft. of treated surface. The saltpeter is added after the steel has been placed in the sulphuric acid solution and its addition is followed by a violent eruptive action on all metal surfaces within the vat, which, by the way, is constructed of redwood timber. After this action has subsided the steel is removed from the cleaning solution and again washed with a jet of water preparatory to the plating operation. Lead plating is effected by dipping the steel in a vat filled with lead acetate solution ranging from 20 to 50 per cent for a period of about 20 min. About 0.1 oz. of lead is deposited per square foot of steel and the weight of this lead plating can then be built up electrochemically if desired.

It is stated that the resultant material retains all the physical strength of the steel superstructure and is as impervious to corrosive action as pure lead.

The article describes also the new method of making pipe joints by means of forged steel flanges welded to the tube ends. (*Railway Review*, vol. 71, no. 24, Dec. 9, 1922, pp. 818–820, 3 figs., *d*)

Carbonized Clay—A New Refractory Material, Walter Smith. General discussion of the carbonization of clays with special reference to the osmose process and material produced thereby.

In general carbonization of clays is based on the fact that clay reaches maximum porosity in the earlier period of firing at a point when the clay is in the biscuit state. The material is then extremely absorbent. This opportunity is seized for charging the clay with volatilized hydrocarbon. As the heating is continued the clay powerfully contracts and entraps the particles of atomic carbon which are then compressed from the easy position adopted by themselves by volatilization to a great density. The product thus made is carbonized clay.

Black carbonized clay consists of clay grains reinforced with countless infinitesimal particles of carbon diffused throughout the pores. This material is remarkably dense, and so long as it remains in a reducing atmosphere is capable of withstanding the destructive action of heat beyond the highest commercially workable temperature and is unaffected by acids.

White carbonized clay results from the action of an oxidizing flame on black carbonized clay. When such a flame plays on the black material myriads of particles of enclosed carbon are gradually consumed, a corresponding number of minute pores being created.

Thus, instead of having the porosity which occurred naturally in the biscuit state of the clay (uncontracted), there exists an artificial (and almost equivalent) porosity in the fully contracted material, and, since the contractive force of the clay has been expended, the artificially created pores remain constant. In other words, when further heating is applied to the mass, the limit of contraction having been reached, difficulty is encountered by the heat in bringing about a state of fusion; the fusing point is therefore transferred several hundred degrees higher than that of the same clay in its natural state.

The black state provides a material adapted for heat resistance in reducing atmospheres, for the manufacture of acid-resisting ware, and for abrasive powders. In the white condition the clay should be used for the manufacture of refractory materials to be employed in the open flame, and in furnaces where air is freely admitted.

It is stated that the material is very little affected by hot acid fumes, both hydrochloric and sulphuric acid. The hardness of carbonized clay is just short of carborundum; indeed, it might replace the softer grades of carborundum and the material is amorphous instead of crystalline. Its heat conductivity is twice that of standard firebrick. A specimen was shown which was intact after resisting a temperature of 1730 deg. cent.

A remarkable phenomenon which occurs as a result of carbonizing clay is the fact that by carbonization iron oxide may be liberated from clay as a by-product. Alkalis are similarly liberated. (*Journal of the West of Scotland Iron and Steel Institute,* vol. 30, no. 1, Oct., 1922, pp. 8–13, *dA*)

Marine Borers Attack Piling Along Atlantic Coast. In the report of the San Francisco Bay Marine Piling Committee (compare Mechanical Engineering, Dec., 1922, p. 834) it was mentioned that the marine borer had appeared on the Atlantic coast. It is stated now that the National Research Council has undertaken an investigation to determine methods of protection. The first appearance on the East coast was established in Barnegat Bay, New Jersey, in 1921. In order to secure definite information regarding the distribution of the various species and their rate of growth, a test board was designed carrying 24 blocks, one of which was to be removed on the first and sixteenth day of the month and sent to Harvard University or the University of California for proper investigation. The blocks are 2 in. by 4 in. by 5 in. in size, of whitering sappy yellow pine, surfaced on four sides. The first boards were placed in June, 1922, and altogether 235 of these boards have been put in place between the eastern boundary of Maine and Kodiak, Alaska. As a result it was found that the various types of borers are present practically along the entire coast.

In an effort to develop a system of protection, test blocks impregnated with various chemicals, in particular fractions of creosote, are being tested by immersion in Gulf and Pacific harbors, several tropical woods being also included in the test. A report on this work has not been published as yet. Reinforced concrete as a substitute for timber has not a record of useful success; in fact, the Committee has found very many more cases of failure than of success, and in most cases the causes of failure are very obscure.

This investigation is being conducted by the Committee on Marine Piling Investigations of the National Research Council, New York City. (*Railway Age,* vol. 73, no. 24, Dec. 9, 1922, pp. 1083–1085, 5 figs., *g*)

FOUNDRY

Casting of Aluminum Bronze, Chas. Vickers. Aluminum bronze requires some special methods of casting as compared with the practice of a brass foundry. It drosses and shrinks excessively and is also subject to gas cavities and internal shrinkage holes. Furthermore, machining is apt to disclose little nests of a white non-metallic substance (alumina). In the case of castings massive in size the alloy changes as it cools slowly in sand molds and suffers thereby a drop in tensile strength and particularly in elongation. (This change, known as "self-annealing," has to be counteracted either by some device for the quick chilling of the casting or by the use of special compositions of aluminum bronze immune to the effect of slow cooling.)

The article describes in detail how to counteract these undesirable tendencies in castings, in particular the method of gating used. Among other things it is recommended to use horn gates with the large end toward the casting and heavy risers to feed the shrinkage. Spiraling of the down gate is also suggested, and it is stated that a spiral runner of small cross-section is an important means of securing dross-free castings of aluminum bronze, because it eliminates vertical sprues of large size down which it is impossible to drop the liquid bronze and not create an excessive amount of dross.

The term "aluminum bronze" can be taken as meaning any alloy of copper and aluminum, with or without additions of other elements which have a base of copper. An alloy commonly used for small castings is copper, 89 per cent; aluminum, 10 per cent; and iron, 1 per cent. This has some advantages over the alloy of 90 per cent copper and 10 per cent aluminum. Where great strength is required, as in the case of large valve stems, shafting, etc., an alloy of copper, 86 per cent; aluminum, 10 per cent; iron, 4 per cent, is extensively used. Since this alloy was devised by the author in 1916 it has been extensively used under a variety of names, a proof of its remarkable qualities. In 1918, patent No. 1,264,459 was granted from the application filed Sept. 27, 1916. Its physical properties will vary according to the skill with which it is made. In tensile strength the cast metal should reach considerably over 80,000 lb. per sq. in. and its elongation should not be under 17 per cent, sometimes running as high as 30 per cent. (*The Foundry,* vol. 50, no. 23, Dec. 1, 1922, pp. 958–960, 4 figs., *d.*—In this connection it may be of interest to note that the first comprehensive account of the properties of aluminum bronze published in this country was printed in the Transactions of The American Society of Mechanical Engineers, vol. 15, p. 631, discussion by Mr. Leonard Waldo, Mem. Am.Soc.M.E.)

FUELS AND FIRING

Factors Affecting the Use of Air in Oil Burning, with Comparison of Cost, W. C. Buell, Jr. Discussion of the influence of air pressure in burning liquid fuels. The author classifies all oil-burning systems offered for industrial heating practice into three general types on a basis of air pressure at the source of supply from which they operate, these three classes being: (1) Burners employing so-called "volume" air which is moved by high-speed fan blowers and delivered to the burners at pressures of from 4 to 10 or 12 oz.; (2) burners operating on so-called "positive" air which is delivered to the burners by displacement or turbine-type machines and occasionally by high-speed centrifugal fans, at pressures of from 12 oz. to 2 lb.; (3) burners utilizing "high-pressure" air which is delivered to the burners from compressor lines in which pressures ordinarily run from 50 to 60 or 100 lb. gage.

The author discusses the factors affecting the use of air in oil burning under the above classifications, but with reference to the equipment included under class 1, it should be understood that burners operating on the low pressures of this class cannot depend on the air to atomize the oil but must of necessity use a mechanical system in which the oil fuel is atomized by the static oil pressure forcing the oil fuel through very small orifices in the form of a fine spray which the low-velocity air can easily pick up. The use of this system is therefore limited to oil which is very fluid and very clean. This confines it to a comparatively small field, as in this day and age only residual and heavy fuel oils should be considered as fuels.

The investigation of the author covers the subject of air velocity, quantity of air required for burning oil, inductive properties of primary air as applied to oil-burning practice, comparison of blowers, and, finally, comparative costs of air.

The author comes to the conclusion that consideration of the subject-matter and figures of this paper clearly show that the proper method of burning oil is with air pressure under classification 2, or under some conditions with 15-lb. air under classification 3.

Further, all fuels are high priced whether they are coal, natural gas, manufactured gas or the liquid hydrocarbons, and in the years to come the tendency will probably be for fuel prices to continue on an upward trend; therefore, to cut down fuel costs to the lowest possible figure it is necessary that all of the economic factors entering into combustion reactions be given the most careful consideration and sound engineering principles applied to the installation, application, and operation of all fuel-burning equipment.

The conclusion drawn throughout the paper can be applied with only slight modifications to the combustion of pulverized fuel. Naturally the requirements for atomizing as with oil are present only to a small degree, but undoubtedly the practice is similar with both types of fuel.

No attempt has been made to cover oil-burning equipment as used in the firing of steam boilers and open-hearth, glass, or other regenerative or recuperative furnaces. Conditions of combustion

set up with the latter type of equipment vary so radically from those found in industrial-furnace application that the results given in this paper can in no way be applied. (*Proceedings of the Engineers' Society of Western Pennsylvania*, vol. 38, no. 6, July, 1922, pp. 201–221, 11 figs., *cpA*)

HANDLING AND CONVEYING (See Special Machinery)

HEATING (See Thermodynamics)

HEATING AND VENTILATION (See Power-Plant Engineering)

INTERNAL-COMBUSTION ENGINEERING (See also Motor-Car Engineering)

Research on Small Drilled Orifices, W. S. von Bernuth. Data of tests carried out at Purdue University with special reference to the extremely small holes needed in carburetors and vaporizing devices, including a description of the special apparatus designed for the testing.

It is stated that insufficient data are available on the performance of small orifices. When applied to carburetors it is found that the same-bore orifice would change the metering characteristics, depending on temperature of the fuel, design of the orifice with respect to its length of bore, area of approach, discharge, and various other factors.

The article is devoted mainly to a description of the experimental equipment and states that at the present time data are available on 56.5 Be. gasoline, 41.2 Be. kerosene, and distilled water. It also gives a chart showing actual discharge and effect of temperature on orifice discharge with gasoline, the orifice diameter being 0.030 in. and the thickness of orifice plate 0.5 in., with the discharge plotted against fuel temperature and head on orifice. (*The Automotive Manufacturer*, vol. 64, no. 8, Nov., 1922, pp. 7–8, 3 figs., *e*)

Farman Aviation Motor, 600-Hp. 18-Cylinder W-Type. In this motor the cylinders are 130 mm. (6.1 in.) bore by 180 mm. (7.1 in.) stroke, located in three rows 40 deg. apart. This angle of 40 deg. was determined with a view to having a steady torque, the motor giving 18 impulses in each two revolutions or 720 deg., which gives one power stroke for each 40 deg.

The crankshaft has six throws. The use of a W-type motor was considered to be of advantage as it reduces the size of the crankcase. The increase in the number of cylinders leading to a reduction of the unit cylinder volume permits of a higher compression without fear of self-ignition owing to heating of the center of the piston. The weight of the motor with its full equipment of ignition carburation pumps, etc., is only about 780 kg. (1716 lb.) for an effective horsepower of about 800 at 2200 r.p.m. (The nominal rating of the motor is 600 hp. at 715 r.p.m.)

The motor drives the propeller through a reducing gear weighing 45 kg. (99 lb.). In addition to this there is a 1200-watt generator with a wireless-telegraph alternator weighing 34 kg. (86 lb.), and the total weight of the motor with all accessories including propeller hub is 920 kg. (2025 lb.). The cylinders are grouped in pairs and the compression ratio is one to six.

The cylinders are made from forgings and welded together in pairs. Each pair has a common water jacket made of sheet steel and welded over the group. There are four valves per cylinder, these valves being made of high-nickel steel. Each valve has two concentric springs wound in opposite directions and each cylinder carries three spark-plug bosses, two side by side and the third 180 deg. therefrom; this third boss is intended for the insertion of starting devices, be they explosive cartridges or compressed-air plugs. The article describes in some detail the design of such parts as crankshaft, pistons, valve gear, ignition and lubrication. In connection with this latter it is of interest to note that the oil filters are so arranged that they can be inspected while the engine is running. A safety valve is provided on the oil circulation pump to open when the oil pressure becomes excessive. The purpose of this is to prevent the breaking of the oil radiator at starting in cold weather when the oil is very viscous. Four Zenith carburetors are provided, two with single outlets and two double ones, each outlet feeding three cylinders. The carburetors are fed by two A M fuel pumps connected in parallel to each pump, being, however, of sufficient capacity to supply fuel to all the four carburetors. There is a device for setting these pumps in operation automatically as soon as the electrical starter begins running, in addition to which the pumps may be also started by hand. As it would be impracticable to start a motor of this size by hand, an electric starter has been provided. (*L'Aéronautique*, vol. 4, no. 42, Nov., 1922, pp. 343–347, 8 figs., *dA*)

Small British Two-Stroke Cycle Marine Engine

Bruntons Two-Stroke Marine Engine. Description of an engine built by Bruntons, of Sudbury, England, in which some novel features are embodied. The cylinder diameters are $2\,^5/_8$ in. bore and the stroke is 3 in. On brake test 6 hp. was obtained when running at 1000 r.p.m. which was raised to 8 hp. at 1400 r.p.m. The engine is illustrated in Fig. 1. The pistons are of aluminum alloy and are provided with two cast-iron piston rings at the top and a third one at the bottom. The connecting rods are made of nickel-chrome steel and are fitted with phosphor-bronze bushes to receive the gudgeon pins, and with roller bearings at the big ends.

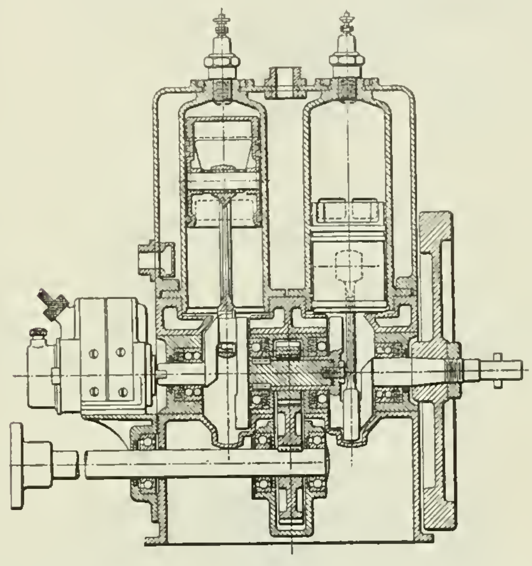


Fig. 1 Bruntons Two-Stroke-Cycle Small Marine Engine

A double-helical toothed wheel on the crankshaft, at about the center of its length, engages with another wheel on the lower shaft, for which a speed one-half of that of the crankshaft is obtained. The crankshaft runs in ball bearings. To prevent the air leakage that would otherwise take place an effective oil packing is arranged with the use of a phosphor-bronze casting with concentric grooves cut in it. The speed reduction gearing is kept completely isolated from the two separate crank chambers. A positive gear pump which is driven by a chain from the propeller shaft, is used to circulate the water required for cylinder cooling. Magneto ignition complete the equipment of what constitutes a complete power unit. The endeavor to produce a small two-stroke unit under conditions suitable for obtaining high efficiency and at the same time with a speed for the driving shaft which is suitable for the use of a reversible propeller, has engaged the attention of engineers for a considerable time, and this installation is not lacking in interest to all who have been faced by this problem. Among other engines described, particular attention is called to the Kelvin engine with single-sleeve valves built under the Burt-McCullum patents. The single sleeve has a motion which is a combination of a reciprocating vertical movement and a turning action upon the sleeve. Double inlet and exhaust ports register with ports leading through the cylinder walls, permitting entry and exhaust of the gases. (The Marine and Small Craft Exhibition. *Engineering*, vol. 114, no. 2969, Nov. 24, 1922, p. 645, 3 figs. Complete article p. 644–647, 10 figs. *d*)

MACHINE PARTS

Reversing Gear for Marine Turbine

Epicyclic Reversing Gear for Ljungström Marine Turbines. The interest in this transmission—which is not new in itself—lies in the fact that it is applied on a turbine-driven steamer of 2150 aggregate effective horsepower. The boat in question, the *Pacific*, which is owned in Denmark, is of 7400 tons dead weight, and is driven by a Ljungström steam turbine running at 3000 r.p.m. and designed to operate with steam supplied at a stop-valve pressure of 185 lb. per sq. in. and a temperature of 662 deg. fahr. The Ljungström turbine has two intermeshed rotors turning in opposite directions and it is always mounted on top of its condenser.

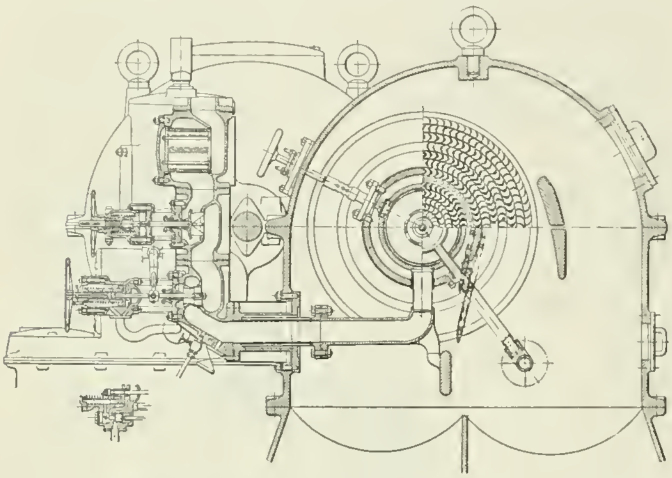


Fig. 2 General Arrangement of the Ljungström Epicyclic Reversing Gear for Marine Turbines

The general arrangement of the gearing is shown in Fig. 2, which represents diagrammatically a plan (partly in section) of the turbine first transmission shaft, reverse gear, the second reduction gear, and the thrust bearing. Each rotor shaft carries a pinion which drives a double-helical gear wheel on the first transmission shaft. As the two rotors turn in opposite direction an idler (not shown) is interposed between the rotor pinion and the gear wheel. In this first stage the speed is reduced from 3000 r.p.m. to 540 r.p.m., which is further reduced to 70 r.p.m. in the second reduction stage shown to the right of the reverse gear.

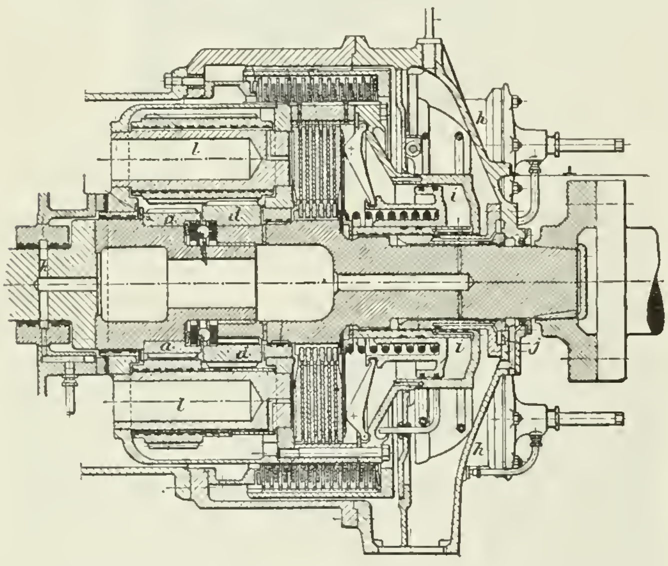


Fig. 3 Detailed View of Thrust Bearings and Lubrication in Ljungström Epicyclic Reversing Gear for Marine Turbines

The details of this reverse gear are illustrated in the original article, which also contains several diagrams together with a detailed description of the operation of the gear.

The oil for lubrication purposes enters at the port k, shown on the left, and as it escapes is collected in the fixed housing and conveyed away for filtration, after which it is again circulated through the system. The wheels a and d are clearly shown to the left of Fig. 3, and as will be seen, a ball thrust bearing is interposed between the opposing ends of the two shafts. This bearing has, it will be seen, an elastic seating on the left-hand side, which consists of a slightly dished steel ring similar to a component of a Belleville spring. Similar elastic cushions, it will be noted, are provided at each end of the outer multiple plate clutch. The planet pinions are mounted on hollow steel studs as shown at l, Fig. 3. They are themselves lined with white metal, and the bearing is supplied with oil under pressure through the ports shown to the right. Of each pair of pinions, one has teeth covering half its length only, as is best seen near the bottom of Fig. 3. This toothed portion gears with the wheel a and with its fellow-pinion which, as shown at the top of Fig. 3, has teeth extending over its full length and gears with the wheel d.

It will be seen that with this arrangement for reversing there is no necessity for stopping the turbine when maneuvring, and the gears are so well lubricated that even continuous slipping of the clutches causes little rise of temperature. Nevertheless provision is made by which in maneuvering the turbine speed is automatically reduced to 50 per cent of its normal value; the maneuvering wheel is fitted near the stop valve and is coupled up to the steam regulating valves so that during a change over the steam is partially shut off. A diagram showing the alterations in the turbine and propeller speeds during a change over shows that the maximum temperature rise did not exceed 20 deg. cent.

The T. S. *Pacific* has been twice to Australia, and has since returned to Denmark from a voyage to Honolulu. The reports from the owners are highly satisfactory. The total consumption of coal per day has been on an average 23 tons for all purposes with the turbines developing about 2300 i.hp., or 0.92 lb. of coal per i.hp. per hour. Average bunker coals were used, and the percentage of ash was on an average $16^1/_2$ per cent. When burning oil the consumption has been 16 tons per day.

A second vessel, the *T. S. Stal*, has also been fitted with a turbine of the same type developing 1350 i.hp. In this case the reverse gear is placed abaft the main-gear casing in order to increase its accessibility. (*Engineering*, vol. 114, no. 2971, Dec. 8, 1922, pp. 699–703, 24 figs., *dA*)

MACHINE SHOP

Hob Making and Special Cutter-Grinding Machinery

Simmons Method of Hob Making, Charles O. Herb. In the Simmons method a standard worm thread is first milled on the

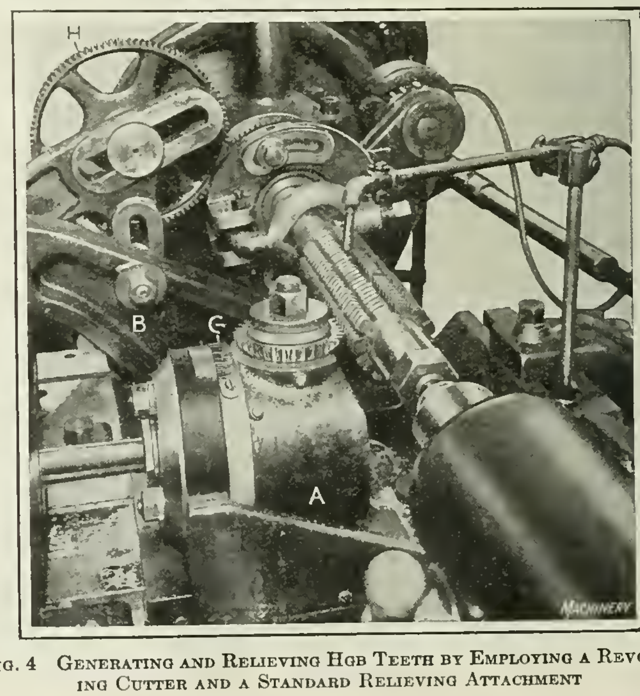


Fig. 4 Generating and Relieving Hob Teeth by Employing a Revolving Cutter and a Standard Relieving Attachment

hob in a thread-milling machine by means of a straight-sided formed milling cutter. After heat treating this preliminary thread is "generated" to the true tooth form in the relieving lathe by the action of a rotating cutter somewhat similar to that employed on the Fellows gear shaper. Because of the action of the cutter the teeth are of the true involute form and mesh with standard gears of the same diametral pitch. The front face of the cutter teeth has a rake of about five degrees.

The two operations of particular interest in this process are the relieving operation which is performed in a lathe which, in addition to the standard relieving attachment, is equipped with a special attachment mounted on the carriage, and the grinding of the cutter teeth done in a machine designed for this purpose. The special attachment used in performing the relieving operation (Fig. 4) consists essentially of a cutter head A mounted on a special cross-slide of the lathe and a unit attachment to the front of the carriage for transmitting the rotary motion to the cutter. Power is delivered to this unit by means of a gear on the headstock spindle directly in back of the faceplate which meshes with idler gear H on bracket B. This idler gear, in turn, drives a gear K on the forward end of the large screw C, which is also designated by the letter C in Fig. 5.

From this screw power is transmitted through worm wheel D and sliding shaft E. At the cutter-head end of the sliding shaft is an integral bevel gear which meshes with a second bevel gear on the lower end of cutter shaft F. By designing shaft E to slide through worm wheel D the cutter may be moved toward the work at the same time that the carriage is operated along the ways of the

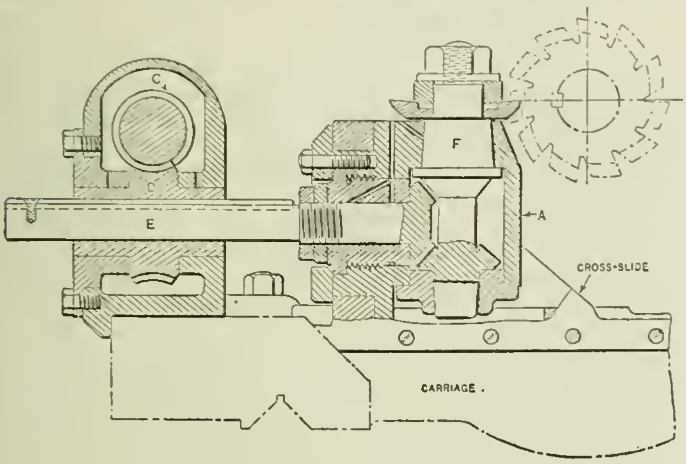


Fig. 5 Cross-Sectional View Through the Cutter Head and Driving Unit of the Special Generating Attachment

bed, either by hand or by means of the feeding mechanism. The gear at the end of screw C is chosen to suit the cutter and has two and one-half times as many teeth as are in the cutter.

After the cutter has been set properly relative to the hob teeth and gashes, and the dog on one end of the work arbor has been clamped to the faceplate to eliminate lost motion, if the cutter is moved away from the work, along the bed, and then forward toward the work again, its teeth will always properly engage the spaces between the hob teeth. This is certain, because the rotation of the cutter and the rotation of the hob are always correlated. When the carriage is moved along the bed, the cutter rotates faster than when the carriage is stationary, due to the rolling of worm wheel D on screw C.

The cutter for producing gear hobs is inclined so that as each tooth engages the work, the face is in a plane at right angles to the helix of the hob thread. The hob teeth are therefore "generated" rather than "formed." The cutters are made from forged disks. These disks are rough-drilled, rough-faced on both sides and rough-turned in a lathe, given an annealing and then permitted to season. The next step consists of finish-boring, finish-facing both sides, and finish-turning the peripheral surfaces to the required angles.

The cutter disks then undergo several machining and grinding operations, of which the most interesting is that of grinding the tooth profiles. For this purpose a special machine described in the original article is used. (*Machinery*, vol. 29, no. 4, Dec., 1922, pp. 255–260, 11 figs. *d*)

MARINE ENGINEERING (See also Machine Parts)

Discarding Geared Turbines. It is stated that several ship owners are removing geared turbines and replacing them by reciprocating engines. Two American-built steamers, the *Wildomina* and *Sylvia Victoria*, which were fitted with geared-turbine machinery are in the hands of a Clyde firm which is substituting for it ordinary triple-expansion reciprocating engines. Other ship owners are said to be showing a disposition to revert to reciprocating engines for their new vessels. The 11,300-ton steamer *Port Hardy*, for the Commonwealth and Dominion Line, recently launched, is to be fitted with twin-screw triple-expansion machinery developing 4500 i.hp. It is said that the *Port Hardy* had really been designed for geared turbines, but there had been a great deal of trouble with the double-reduction-geared turbines and as the line already had seven vessels with turbines they preferred not to continue with that type of engine until they had gained a little more experience. Quite possibly they would return to that type at a later date. The last ship, the *Port Hunter*, had run trials on turbine engines which had proved to be among the smoothest they had giving great hopes for the future. (*Practical Engineer*, vol. 66, no. 1866, Nov. 30, 1922, p. 344, *g*)

METALLURGY

New Type of Open-Hearth Furnace. Description of the Loftus furnace, a producer-gas furnace wherein the producer gas is discharged from a restricted nozzle into a mixing chamber serving to induce the necessary air for combustion. A booster supply of regenerated air is withdrawn from the regenerative chamber, passed through a special chamber driven by a variable-speed motor and introduced into the center of the stream of gas in the direction of its flow through the furnace. The pressure and volume of this booster supply of regenerated air may be governed by the control of the variable-speed motor, in this way giving the operator control over the flame. With such a furnace construction more efficient combustion is obtained, as shown by the actual operation through the mixing of the air with the gas in the hot mixing chamber. The air and gas enter an extremely hot mixing chamber in the form of an outer envelope of air completely surrounding an annular ring of gas containing an inner core of air which is calculated to produce an extremely intimate mixture. This mixture is discharged from the mixing chamber in the form of a flame having practically no stratification and with the utmost compactness and continuity of construction. The operator can control the flame by regulating the pressure and flame of the booster supply of regenerated air. If he wishes he may melt down a charge with a short hot flame and refine with a long mellow flame which completely covers the bath without extending through the outgoing channels.

The original article describes and illustrates the furnace in some detail. Such a furnace has been operating on producer gas at the Ohio Works of the Sharon Steel Hook Co., Lowellville, Ohio, since June 8, 1922. While the charging conditions were not ideal the furnace is said to have produced an average of approximately 30 per cent more steel than the other furnaces in the plant on approximately 30 per cent less coal per ton of ingots. The furnace, up to December, 1922, has given more than 300 heats and from all indications it is believed it will run about 400 heats or more, making an increase of about 50 per cent in its usual life. The repairs have been almost negligible as it has been possible to get almost 100 heats from back and front walls and approximately 80 heats off the gooseneck. (*The Iron Age*, vol. 110, no. 26, Dec. 28, 1922, pp. 1677–1679, 5 figs., *d*)

Ingot Corner Segregation in a Nickel-Chrome Steel, T. Henry Turner. In investigating by means of sulphur prints an octagonal chrome-nickel steel forging the author discovered the presence of planes of segregation. Such planes were found at the angular portions of the ingot and represent the meeting of crystals which have grown from the cooling faces into the still liquid metal. The author believes that such forgings should be rejected even though the mass of the material may possess good chemical and mechanical properties, as the defects, consisting in planes of segregation, entirely negative these good properties and make the forging as a whole treacherous and unreliable in the extreme.

The author makes the following recommendations:

1 That the bell-shaped cylinder design should never be used unless the supplier can guarantee—

a Absence of planes of segregation in the material

b Adequate working during the forging operations.

2 That in cases where the supplier cannot guarantee adequate working of the material during forging (owing to the nature of the design and the limitations imposed upon his work by the nature of his available tools), a composite ring made up of two or more rings, which can be manufactured by a satisfactory forging or rolling, would probably prove more reliable.

3 That the final rolling of such rings is to be preferred to forging them throughout, in that it would tend to produce greater uniformity of dimensions in the rough, and therefore economy in machining. Also it should produce a better and more uniform internal structure and greater uniformity of mechanical properties.

4 That in the case of all large forgings which will be subjected to appreciable circumferential loading, the supplier should be asked to face up both ends of the block of steel before forging is commenced. Sulphur prints should then be taken and forging only proceeded with after these have been passed as satisfactory. Such an operation would, of course, be costly, but it would only be advisable when appreciable hoop stresses are expected.

5 That in cases where the steel maker considers recommendation No. 4 impracticable, the elimination of ingot corner segregation may be achieved by forging down octagonally and machining off the corners which would still contain the segregation. This suggestion is perhaps the most useful and that most likely of successful adoption.

6 That the centrifugal casting of steel for such large cylinders or rings, and even for large turbo-generators rotors, is feasible and worthy of serious consideration. (*Engineering*, vol. 114, no. 2969, Nov. 24, 1922, pp. 662–664, 9 figs. Compare also abstract in *Iron Trade Review*, vol. 71, no. 25, Dec. 21, 1922, pp. 1695–1700, 5 figs. *dA*)

MOTOR-CAR ENGINEERING

Chevrolet Copper-Cooled Car, J. Edward Schipper. Description of an air-cooled car the particular feature of which is that it employs copper fins electrically welded to cast-iron cylinders.

To manufacture the copper-cooled engine it has been necessary to develop machinery to form the copper ribs, and apparatus to handle commercially the electric welding of the formed ribs to the cylinders. The copper fins are made in a special machine which takes the sheet copper and forms it into the proper shape, reducing the depth of the fins or loops at points where clearance for the valve push rods and adjacent cylinders is required. The copper is so formed that the loops are closed at points adjacent to the cylinder barrel, and in such a way that a continuous band of copper is in contact with the outer wall of the cylinder, which latter is machined both inside and out.

The cylinders are manufactured singly but are assembled in pairs. Between the cylinders in each pair, which are closely adjacent to one another, the fins are graduated in size so that there is no interference.

The cooling is by air forced through and around the fins and over the cylinder heads by a centrifugal blower made largely from sheet aluminum alloy. This blower is in front of the engine and is driven by a special form of V-belt from a pulley on the crankshaft. Air enters at the bottom of the fins around the cylinders. A light steel stamping forms a tubular draft tube which fits closely around the cylinders so that air can enter the fan only by passing upward through and around the copper fins and through the space above the cylinders. The V-belt employed has a woven-cord construction on its neutral axis and a durable elastic material on either side of the neutral axis permitting of the flexing necessary for the drive. The drive for the fan is triangular, the belt passing around the crankshaft fan and generator pulleys. Adjustment for the tension of the belt is secured by swinging the generator, which is mounted on the left side of the engine. The engine, it may be noted, is the first "square" one to be placed on the market for some time, both bore and stroke being $3^1/_2$ in. With a compression ratio of four to one it develops a maximum brake horsepower of 22 at 750 r.p.m. (*Automotive Industries*, vol. 47, no. 26, Dec. 28, 1922, pp. 1259–1265, illustrated, *d*)

PHYSICS

Temperatures at Which Physical Changes Occur, Henry D. Hibbard, Mem. Am.Soc.M.E. A list of some of the temperatures relating in one way or another to the production and heat treatment of steel and to the fusibility of steel and of its components. Of these the following, all belonging to the higher ranges, are of interest:

Degrees Temperature Cent.	Fahr.		Degrees Temperature Cent.	Fahr.	
1750	3182	Pure silica melts	2220	4028	Carborundum decomposes without melting
1755	3191	Platinum melts	2450	4442	Iron boils
1795	3263	Titanium melts	2500	4532	Zirconium oxide melts
1820	3308	Bauxite melts	2550	4622	Molybdenum melts
1900	3452	Manganese boils	2572	4662	Lime (CaO) melts
2050	3722	Chromite bricks melt	2750	4982	Vanadium carbide melts
		Pure alumina melts	2800	5072	Magnesia (MgO) melts
2059	3738	Chromic oxide (Cr_2O_3) melts	3176	5750	Tungsten melts
2165	3929	Magnesia brick belts	3600	6512	Molybdenum boils
2180	3956	Chromite melts	3700	6692	Carbon is vaporized
2200	3992	Chromium boils	5200	9392	Tungsten is vaporized
		Silicon boils			
		Aluminum boils			
		Graphite made from amorphous carbon (2200 to 2400 deg.)			

An interesting discussion is also submitted as to the proper definition of the melting point of a substance and the temperatures near the melting point which bear some relation to it. Some of these are practically useful and some have only a scientific value. These are:

1 The temperature at which the substance sinters, as a clay. This is useful. It is below the fusion point, No. 4.

2 The highest temperature at which a vessel made of the substance can be used. Instance a porcelain crucible. This is useful. It is lower than No. 1.

3 The temperature at which it softens in any degree which, as in a firebrick, limits its usefulness. This is useful. It is lower than the fusion point, No. 4.

4 The temperature at which its edges are rounded. This is often called the fusion point and is generally the one given in the table. It has only a scientific value.

5 The temperature at which it becomes fluid. Instance a slag. This is interesting, but taken alone is not useful. It is above No. 4.

6 The lowest temperature at which it may be handled molten in practice, as a slag or metal in a metallurgical operation. This is useful. The temperature may be 50 or 100 deg. cent. (90 to 180 deg. fahr.) above No. 5 as the substance leaves the furnace (*The Iron Age*, vol. 110, no. 23, Dec. 7, 1922, pp. 1492–1493, *g*)

POWER-PLANT ENGINEERING (See also Engineering Materials; Fuels and Firing)

Boiler-Tube Failures

Boiler-Tube Failures, Haylett O'Neil. The author claims that in a modern boiler plant, well designed and well operated, that is, where the boiler is clean and proper internal circulation is maintained, boiler-tube failures are infrequent. There may occur, however, conditions under which boiler tubes fail, and he describes one such case which gave considerable trouble.

In general, boiler tubes may fail where there is a condition producing sufficient unevenness of temperature to cause rates of expansion in adjacent parts of a tube varied enough to strain the metal. In a case described by the author it was found that little trouble was experienced from boiler-tube failures in the spring and summer, but the tubes would fail rapidly in the late fall and winter. An investigation showed that excessive scale was deposited from water during these two latter periods, no water softening being used. Furthermore, during the dry season feedwater was drawn

from a spring in which the water was charged heavily with bicarbonate of lime. Careful records presented in the form of curves in the original article show a clear relation between the use of spring water and tube failure. Scale deposited on the tubes would give a uniform heat insulation, therefore, blisters would not occur, but the tubes cracked square off at the front end in nearly all cases.

In the ordinary vertically baffled boiler the author has noticed that under similar scale conditions the tube generally bows down. This indicates that the under side of the tube has been heated hotter than the upper, which is reasonable with this arrangement of baffling, and hence has bulged toward the fire.

In a clean boiler the temperature of the metal is practically equal to that of the adjacent water, but scale insulates the metal of the tube from the water. In that case the hotter the gas is the hotter will be the metal, irrespective of the water temperature. How, then, does the top of the tube get hotter than the bottom? The answer in one case proved to be that the T-tile kept the top of the tube hot during both normal operation and part of the cleaning periods. The temperature of this tile according to the pyrometer was close to 2500 deg. fahr. The lower part of the tube was surrounded by furnace gas which fluctuated between 2500 deg. during firing conditions and about 1200 deg. during cleaning periods. Inasmuch as during a cleaning period the front doors had to be open, temperature variations could not be eliminated.

On account of the heat conductivity of the iron it would naturally be impossible to maintain for any considerable time a temperature difference between the top and bottom of the tube, but calculations have been made by the author indicating that only a few hundred degrees difference is required to curve an 18-ft. tube as much as 3 in. out of line. Such a temperature difference seems to be entirely feasible.

What actually happened is this: At first a tube would be humped upward slightly during a cleaning period and restraightened afterward as soon as the bottom could be expanded under the influence of the furnace temperature. Every time cleaning or banking took place the expansion and contraction cycle was repeated. Therefore the tube was subjected to repeated bending upward and downward several times a day. The strains were concentrated at the tube sheet, where finally the tube became brittle and lost its tensile strength. Finally, the tube would be strained beyond its elastic limit and take on a permanent set. When the boiler was cooled for cleaning the temperature was reduced nearly to room temperature, causing extreme tension in the tube due to contraction, and the tube would break.

The final solution of the trouble came in the regular adding to the boiler water of an internal treatment, the base of which was caustic soda. A given quantity of this was pumped into each boiler at regular intervals, and twice each week boiler waters were titrated for soda concentration. By keeping the soda concentration under 40 grains per gallon, excellent results were obtained. After a run of from 60 to 90 days on spring water only a thin film of scale was formed, and there was no foaming. The T-tile were finally replaced entirely.

Actual records of tube replacements have shown that this manner of handling the trouble was correct, and certainly no steam-power plant is even approximately safe unless the boilers are kept clean religiously. (*Power*, vol. 56, no. 23, Dec. 5, 1922, pp. 876–878, 7 figs. *pe*)

Tests of a Magazine-Feed Boiler with Special Method of Supplying Secondary Air, John Blizard, J. Neil, and A. Pincus. Data of steaming tests carried out by the Fuel Section of the U. S. Bureau of Mines at the request of the American Society of Heating and Ventilating Engineers on a magazine-feed boiler provided with special method of supplying secondary air to determine its thermal efficiency and other important factors when fired with various fuels.

It was also found that coke, anthracite, lignite char, and various bituminous coals could be burned with little poking and other attention to the fuel on the grate or in the magazine except when cleaning the fire or charging fuel, but that caking Pittsburgh coal was unsuited to this boiler since it had to be poked frequently to break up an arch which formed near the top of the grate.

The outstanding results of the tests were: That the method of admitting secondary air supply over the fuel bed permitted the combustible gases rising from the coke fuel bed to be burned so that only 29 to 58 per cent excess air remained after combustion, those from anthracite with only 35 to 62 per cent excess air, those from Illinois coal with 61 per cent excess air, and those from Colorado coal with only 23 per cent excess air. With all of these fuels the carbon monoxide left in the gas represented only about 1 per cent or less of the heat of the fuel. Therefore, for these fuels the methods of admitting secondary air was good. On the other hand, the carbon monoxide remaining in the gas when burning Pittsburgh coal with 35 per cent excess air represented 7 per cent of the heat energy of the coal, and the unscreened lignite char was burned with 221 per cent excess air, which was reduced in the trial with the screened char to 94 per cent.

The thermal efficiency with coke was highest when operating at about 90 per cent of the maker's rating; at this rating the efficiency was 76 per cent, and dropped to 67 per cent and 70 per cent when operating at 123 and 35 per cent rating, respectively.

Data have also been obtained for other kinds of coal, such as stove and chestnut-size anthracite, briquets, and Pittsburgh coal.

An interesting series of supplementary investigations were also carried on and temperatures above the fuel bed and in one of the central flues were measured; likewise temperatures in the flues of the first and second pass.

Among other things, it would appear that at the highest rate of steaming and the lowest rate but one, the furnace temperatures with coke and anthracite are approximately the same, while at the highest rate but one the temperature was higher with anthracite than with coke by 150 deg. fahr. and at the lowest rating the anthracite furnace temperature was 350 deg. fahr. lower.

Data for other temperatures are given in the original article. (*Journal of American Society of Heating and Ventilating Engineers*, vol. 28, no. 9, Dec., 1922, pp. 833–842, 5 figs., *e*)

Electric Drive in a Sugar-Manufacturing Plant, Roger B. Stevens. Description of the layout of electrical equipment of the recently completed Baltimore plant of the American Sugar Refining Co., the particular feature of which is that practically the entire drive is effected by means of direct-current motors.

There were several conditions which decided in favor of direct current. In the first place the sugar refinery consists of a number of closely grouped buildings with the transmitting distances short and the loads closely concentrated, which make transmission losses small. Furthermore, the conditions of sugar-refinery work are somewhat peculiar. The process from start to finish is continuous. Moreover, the materials are carried at a fairly high temperature and even a small delay leading to loss of heat produces stiffening of the material. Because of this the power required to start a given machine may be from five to ten times that required for operation after the running condition has been established. Nearly all of the refining processes are interdependent and continuous, so that unless large and expensive storage facilities between the various stages are available the several elements of machinery must be capable of close adjustment in speed. Furthermore, in the case of more than 80 per cent of the total horsepower required, either a speed adjustment was absolutely necessary or a very distinct advantage was to be gained by providing such adjustment.

In alternating-current machinery only the slip-ring motor with resistance is capable of an extensive range of speed variation, but it is then only the equivalent of a series-wound direct-current motor and has the disadvantages of moving contacts and vulnerable brush rings. The direct-current motor, on the contrary, is capable of good starting torque and adjustable speed, though it is slightly higher in the first cost. Furthermore, with the close grouping of the loads the comparatively low (230) voltage of the direct-current made the total cost of the distributing system lower than would have been the case with alternating current. This is principally because a large number of motors could be grouped on single feeders to take advantage of the low diversity factor thus obtainable.

The article describes in detail the installations used and the electrical distribution system. (Factors in Industrial Plant Distribution. *Electrical World*, vol. 80, no. 24, Dec. 9, 1922, pp. 1259–1262, 5 figs., *d*. Compare also editorial entitled, An Unusual Case in Industrial Power Design, same issue, p. 1254)

Exploding an Old-Time Boiler Fallacy, W. B. Roberts. Data of tests to show the fallacy of the belief that cold water sprayed upon a red-hot boiler plate instantly generates an uncontrollable volume of steam.

The article is based on tests carried out under the auspices of the Manchester Steam Users' Association on an ordinary Lancashire boiler 7 ft. 0 in. diameter and 27 ft. 9 in. long, shell plates $^7/_{16}$ in. thick and head plates $^9/_{16}$ in. thick. A number of precautions were taken to protect observers from the consequences of the expected explosion and, at the same time, permit them to take the necessary observations. The tests were carried out in such a manner that at 6.30 p.m. there was 25 lb. of steam pressure showing and the safety valves began to blow. At the same time the blow-off top was opened full bore, there being $9^1/_2$ in. of water covering the crown of the furnaces. Within about an hour the level of water was brought to $3\,^5/_8$ in. below the crown of the furnace, this latter laying bare and exposing a strip of plating 21 in. wide at a temperature of about 700 deg. fahr. with a pressure of $28^1/_2$ lb. on boiler, and the safety valve blowing freely. The feedwater having a temperature of 60 deg. fahr. was then turned on, sprayed directly on the red-hot plates with a rate of injection a little more than $4^1/_2$ cu. ft. per min. Showering the feedwater at a temperature of 60 deg. fahr. on a red-hot furnace crown was not attended by an increase of pressure. On the contrary, the pressure at once began to fall and in $2^1/_2$ min. had fallen from $28^1/_2$ lb. to 26 lb.

Upon looking into the furnaces the ring seams of the furnace tubes were found to be leaking freely. The overlaps of the first seven ring seams in each furnace were sprung at the crown, but the shape of the furnace tubes was practically unaltered except that the right-hand tube was slightly bulged in three places.

Other slight consequences of overheating were observable. The main thing, however, which the tests have shown is that spraying fairly cold water on red-hot plates and furnaces did not lead to the ripping of the plates circumferentially or longitudinally, and did not cause any increase of pressure due to a violent and sudden generation of steam. (*Power House*, vol. 15, no. 24, Dec. 20, 1922, pp. 19–21, 5 figs., *eA*)

Discussion of Vapor Refrigerating Condensers for Steam Turbines, F. C. Evans. One of the means of bettering the economy of the steam turbine is to reduce the back pressure. At the present time the back pressure employed is limited to around 1 in. of mercury absolute, corresponding to a temperature of the exhaust steam of about 79 deg. fahr. This limit has been reached with water as the condensing medium, and the author questions whether better results could not be obtained by substituting the cooling coils of a refrigerating system for the condensing-water tubes of the ordinary surface condenser, so as to reduce the temperature of the exhaust steam to about 35 deg. fahr.

For purposes of discussion the author considers a plant where steam is available from the boilers at 200 lb. per sq. in. absolute pressure and 200 deg. superheat, and ample condensing water at a temperature of 60 deg. fahr. but which must be raised 20 ft. He shows that under these conditions the available energy in the steam is 413 B.t.u. per lb. of steam less 1.5 B.t.u. required to handle the water, which gives a net energy for sale of 411.5 B.t.u. per lb. of steam.

When a vapor refrigerating condenser has been substituted for a water condenser, the available energy in the steam operating with the back pressure of 0.205 in. is 486 B.t.u. per lb. But the author shows that the refrigerating system consumes 90 B.t.u., thus giving as a final result 396 B.t.u. of energy available for sale per pound of steam, which is less than when a water condenser is used.

As a result of this analysis it appears that at the present time steps o increase the economy of the steam turbine must be taken in another direction. What this direction may be one cannot say, but it seems impossible to reduce the back pressure of the turbine economically by the use of a vapor refrigerating condenser. (*The Sibley Journal of Engineering*, vol. 36, no. 9, Dec., 1922, pp. 175–177 and 187, 3 figs., *tg*)

Steam and Steam Boilers

Steam and Steam Boilers. An editorial based on Mr. C. E. Stromeyer's report to the Manchester Steam Users' Association.

Among other things the report includes a partial description of some interesting experiments on the strength of very old boilers. Of these one was obtained from Messrs. Pilkington and had been constructed some sixty years ago. The other, supplied by the Metropolitan Water Board, was of somewhat similar date. The experiments are still incomplete, but they indicate pretty conclusively that the material of the shell plates has not deteriorated with time, and that injuries and cracks caused by the punching of the plates had not apparently extended during the very long life of the boilers. Specimens of the material tested showed somewhat erratic results, but it is probable that this was characteristic of the iron made at the period in question. The range of tensile strength was from 17 tons to 25 tons per sq. in. In many of the seams, cracks due to punching extended over several rivet holes, but these do not appear to have had any worse effect than that of reducing the net section of the metal. These observations seem to indicate that factors of safety might reasonably be reduced now in view of the uniformity of the material supplied, the great care exercised in its manufacture and the prevalent practice of drilling all rivet holes.

During a hydraulic test one of the boiler shells "barreled" as first described by Mr. J. C. Spence in a paper read before the North-East Coast Institution of Engineers and Shipbuilders in 1891. On making measurements on a model boiler tested to destruction Mr. Spence found that the shell stretched less at mid-length than it did at a certain short distance from the end plates. The observation was novel at the time, and the curious bulges in question received the name of "Spence humps."

Mr. Stromeyer states that it has generally been thought that the effect of the end plates was to relieve the circumferential stress. This may well be true, but there is no excuse for such misunderstanding for, in the discussion of Mr. Spence's experiments, which appeared in *Engineering*, Apr. 27, 1891, p. 468, it was shown that save in the case of extremely short boilers the effect of the ends was to cause a local increase of the circumferential stress. This was very clearly brought out in Mr. Spence's experiments, and was fully confirmed by the mathematical theory developed in a paper by Mr. (afterwards Professor) J. T. Nicolson, read at the same time as that of Mr. Spence. The subject was very fully discussed in *Engineering*, both editorially and in its correspondence columns, and that the other view should, as Mr. Stromeyer states, still be prevalent is not creditable to boiler designers and constructors.

In another section of his report, Mr. Stromeyer suggests that very slow alternations of stress are more serious than rapid ones. It appears quite possible that in the case of exceedingly rapid repetitions of stress the metal may fail to take the full deformation theoretically due to the load, since, with all materials, when a load is first applied the full strain is not simultaneously achieved. There is always some "after creep" and it is thus quite possible that the metal is less severely tried by very rapidly alternating stresses than by slowly applied ones. The general view has, however, been that at any ordinary rates of alteration the fatigue limit of our structural materials is independent of the rate of repetition. Mr. Stromeyer's view is, however, that the very slow rate of changes of stress to which a boiler is subjected, makes these much more injurious than if the variations were more rapid. This is contrary to the common belief and does not seem altogether consistent with the fact that slightly overstrained metal in time recovers its elastic properties. In support of his theory, Mr. Stromeyer instances the grooving found at the roots of the flanges of dished ends, but grooving is only indirectly connected with the stress on the metal as it is primarily an oxidation process, facilitated by the differences of E.M.F. which arise between strained and unstrained metal. It seems to us questionable, therefore, whether fatigue in the usual understanding of the term is involved in the matter any more than it was in the extraordinary failures of the high-tension bronzes adopted for the Catskill aqueduct. (*Engineering*, vol. 114, no. 2973, Dec. 22, 1922, pp. 775–776, *g*)

RAILWAY ENGINEERING (See also Engineering Materials)

Recent Tendencies in British Locomotive Practice. E. C. Poultney. Beginning of a series in which it is proposed to describe a number of typical recent locomotives built for service

on British railways which indicate the tendencies of modern practice.

Perhaps one of the most striking features is the use made of either three or four cylinders, with the three-cylinder arrangement rapidly gaining favor. (The ordinary British type of locomotive has two inside cylinders.)

Steam pressures have undergone some changes during recent years. Previous to the general introduction of flue-tube superheaters, boiler pressures ranged from about 170 to 200 lb. With the advent of superheating there was a general tendency to reduce pressures to about 160 lb. and increase the cylinder volume. The practice is now toward the higher pressures, and those of 180 to 200 lb. are considered necessary, while cylinder volumes are continually increased to furnish the necessary power; in fact, it is largely the greater cylinder capacity now required that has prompted the introduction of three- and four-cylinder locomotives.

Locomotives now built for main-line working are practically all fitted with flue-tube superheaters, and older engines when requiring extensive repairs and renewals, or to be rebuilt, are as a rule superheated; and when this course is adopted it is usual to fit new cylinders with piston valves. While the type of superheater used is in all instances the same, there are in some cases considerable differences in details. This applies more especially to the design of the headers.

Damper gear has been discarded now by all railways. Automatic air valves are quite often fitted to the steam chests and sometimes on the header (the wet-steam side). Cylinder by-pass valves are not generally used, neither are pyrometers.

From this the author proceeds to describe some of the new locomotives, and in connection with the Great Central 4–6–0 type describes and illustrates the Robinson piston and pressure-relief valve.

An interesting fitting used on the Great Central is what is called an Intensifore lubricator which works in much the same manner as a hydraulic intensifier. Briefly, the arrangement consists of a container filled with oil upon which pressure is applied by means of steam acting as a plunger. Oil is led from the lubricator by suitable piping to distributors mounted on the footplate, usually on the back head of the boiler. The distributors consist of sight-feed glasses fitted with suitable controls, from which the oil is led to the valves, pistons, and also to the driving boxes.

The three-cylinder fast freight engines of the North Eastern are next described and in this connection data are given of some trials made with a 0–8–0 type engine.

The Caledonian locomotive is one of the most powerful 4–6–0 type built for express passenger service. The engine has three cylinders which are all in line and drive on separate axles. The center cylinder drives the leading wheels through a crank axle, and those outside the center coupled wheels through connecting rods 11 ft. long as against 6 ft. 6 in. long for the inside rod.

Several other types are described, among them being a three-cylinder type built for the Great Northern. Here all three cylinders drive on to the center axle and a peculiar valve gear is employed, the valves being of the piston type. There are three of them with inside admission which are operated by two sets of Walschaerts gear applied to the outside motion. (First of a series. *Railway Mechanical Engineer*, vol. 96, no. 12, Dec., 1922, pp. 677–682, 7 figs., *d*)

Effect on Ton-Mile Cost of Reducing Train Loads. Data of tests carried out for the U. S. Railroad Administration on the Illinois Central, from which it would appear that the greatest economy is obtained with full-tonnage freight trains.

The original article describes the method employed in carrying out the tests and gives in tabular form some of the results obtained. Because of lack of space only some of the conclusions can be reported here, as follows:

1 There is no general agreement as to the percentage of tonnage rating which will bring the lowest cost. In the majority of cases this is effected by a load of 100 per cent, but in others the most economical load (considering the cost in one direction only) is about 85 per cent. Each division is governed by its own operating characteristics and no general law appears in the results obtained in this study.

2 The cost per ton-mile decreases as the gross carload increases, due probably to the lower train resistance per gross ton.

3 The cost per ton-mile increased with the delay on the road.

The practical application to that road of the facts developed by the tests is summarized by the following general conclusions in the report of the Federal manager of the Illinois Central:

1 It is not practicable to reduce the train load to avoid overtime because of the increased cost incident to the operation of the necessary additional trains in the direction of heavy traffic to handle the same tonnage and in the direction of light traffic to balance power.

2 To a large extent the cost of handling the most economical train load includes considerable overtime.

3 Increased cost resulting from overtime, like any other wage increase, must be met by increasing facilities instead of by reducing train load. This reduction, in a good many districts, would add train units in excess of present capacity. (*Railway Age*, vol. 73, no. 25, Dec. 16, 1922, pp. 1145–1148, *ep*)

Zeitler Self-Contained Gasoline Motor Truck for Railway-Car Bodies. In this car the truck conforms to a standard railway truck, the frames being cast steel and the engine crankcase forming the hollow bolster. The transmission is hung directly beneath the engine and forms almost an integral part of it. The engine is a four- or six-cylinder horizontal or forced type. The pistons are of the truck types carried in sleeves that act as crossheads and take the wear off the cylinder walls.

The control system is of the electropneumatic type. A small master controller located in the engineer's cab controls the electric starting motor and the carburetor, this latter being governed by a variable-speed electric motor operating the governor attached to the butterfly valve. An electropneumatic arrangement operated also the gear shift.

An interesting feature of the design is the support of the crankcase bolster. This crankcase bolster is spring-supported, a bracket at the ends being extended to a suspension link to permit lateral motion. This suspension link is attached to the frame and at a point on the frame which results in low stresses at the center of the side frame. The springs rest directly on the journal boxes with the ends attached to the side frames, thus giving the crankcase bolster both lateral and vertical movement. The center tie bars between the side frames are bolted in place and therefore can be removed readily. Then by disconnecting the suspension links at the frames, the drive shafts and control connections, the engine and transmission may be removed from the truck for overhauling. (*Railway Review*, vol. 71, no. 25, Dec. 16, 1922, pp. 852–854, 2 figs., *d*)

REFRIGERATION (See also Thermodynamics)

Tests on Ammonia Compressor and Tubular Condensers

Performance of Single-Acting Ammonia Compressor and Tubular Condensers, Geo. A. Horne, Mem. Am.Soc.M.E. Data of tests made in the Tenth Ave. plant of the Merchants Refrigerating Co., New York City. The machine on which the tests were made is a vertical, three-cylinder, single-acting, simple compressor of the enclosed type with pistons 18 in. in diameter and a 20-in. stroke. The machine is direct-connected to a synchronous motor and is operated at 164 r.p.m. The condensers are shell and tube, open type, with water pumped over the top and flowing by gravity through the tubes into an open pan. The condensed liquid is cooled in a double-pipe liquid cooler, from which it passes to a shell and tube brine cooler.

The article describes the equipment used in these tests which appears to be unusually complete for a commercial test. Ammonia was measured by a carefully calibrated meter, which is superior to any method of simply weighing or gaging the liquid during the test.

In view of the fact that the liquid is frequently cooled below the temperature corresponding to the boiling point at the condenser pressure, an interesting chart (Fig. 6) has been arranged so that the percentage of indicated horsepower per ton saved by liquid intercooling may be read directly without detailed calculation.

The chart is subdivided into three parts: (1) the upper left-hand corner gives the relation between condenser pressure, liquid cooling range and B.t.u. removed by water per pound of liquid ammonia;

(2) the lower right-hand corner gives the relation between condenser pressure, suction pressure, and B.t.u. available per pound of ammonia with no liquid cooling; (3) the upper right-hand corner gives the relation between available B.t.u. per lb. of ammonia with no liquid cooling, B.t.u. removed by water per pound of liquid ammonia and percentage of saving in horsepower effected by the liquid forecooling.

The following examples will show how the chart is used:

1 Given: Condenser pressure 190 lb. per sq. in. abs.; suction pressure 20 lb. per sq. in., abs. Find: Available B.t.u. per lb. of ammonia, without any liquid cooling.

Use the lower right-hand section of chart. Enter the right-hand vertical scale at 190 lb. (see dotted line on chart), move horizontally to the right to the 20-lb. suction line; then move vertically down and read 458 B.t.u. on the lower horizontal scale.

2 Given: Condenser pressure 190 lb. per sq. in., abs.; liquid forecooled 20 deg. fahr. (i.e., from 93.1 to 73.1 deg. fahr.) Find: B.t.u. removed by water per lb. of ammonia.

Use the upper left-hand section of chart. Enter the horizontal scale at 190 lb., move vertically up to the 20-deg. line, then move horizontally to the left and read 23 B.t.u. on the vertical scale.

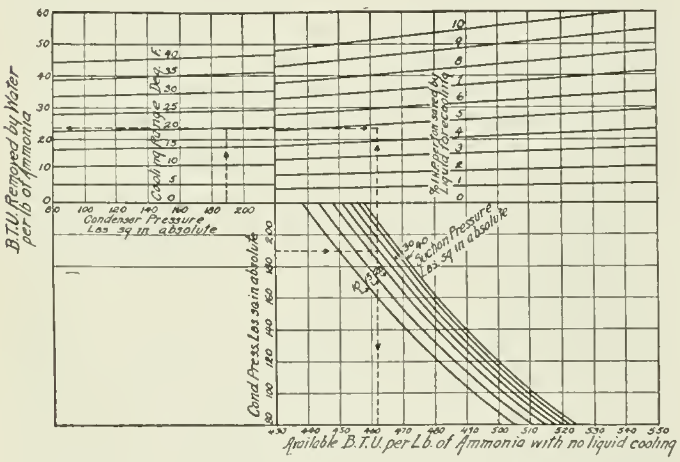


Fig. 6 Theoretical Compression of Ammonia (Simple Compression with Liquid Forecooling)

3 Given: Condenser pressure 190 lb. per sq. in., abs., suction pressure 20 lb. per sq. in., abs.; liquid forecooling range 20 deg. fahr. Find: The i.hp. per ton.

In the lower right-hand section of chart enter the vertical scale at 190 lb.; move horizontally to the right to the 20-lb. suction line, move vertically up; hold this vertical line. In the upper left-hand section of the chart enter the horizontal scale at 190 lb.; move vertically up to the 20-deg. line and then move horizontally to the right until the vertical line previously obtained from the other section of the chart is intersected. At the intersection read 4.8 per cent saving effected by liquid forecooling. From the i.hp. chart we find that the i.hp. per ton for 190 lb. condenser pressure and 20 lb. suction pressure but without liquid cooling is 1.525. Then the i.hp. per ton for the same conditions but with liquid cooling is $1.525 (1 - 0.048)$ or $1.525 \times 0.952 = 1.452$.

It should also be mentioned that the theoretical i.hp. as calculated does not include any saving due to water-jacketed cylinders. The machine which was used in these tests was provided with water jackets, which naturally increases the volumetric efficiency and decreases the horsepower per ton. The effect of the jacket water may be calculated from the data as shown for the various tests.

The table in the original article gives a summary of the condenser performance in these tests, of interest because of the high rate of heat transfer obtained with these condensers. (*Refrigerating Engineering*, vol. 9, no. 5, Nov., 1922, pp. 143–151 and 161, 11 figs., *eA*)

SPECIAL PROCESSES

Mauclere System of Pneumatic Handling of Inflammable Liquids. The apparatus is designed primarily for handling kerosene and other inflammable or toxic liquids. It may be used for any other kind of liquids as well, including viscous liquids and those holding solid matter in suspension.

The problem which the designer undertook to solve may be stated as follows: To assure in every instance by means of "interconnecting gage vessels" functioning alternatively the manipulation of the liquids contained in closed reservoirs in any position or dimension and under atmospheric pressure, with the further restriction that these liquids during the period of storing them in the tanks, withdrawing them from the tanks, and intermediary periods, should remain at all times out of contact with the air in order to avoid diffusion of inflammable or toxic vapors.

The original article describes the apparatus in detail as well as test data in connection with the separation. The apparatus is of such a character that it may be applied either to a large stationary plant or to a delivery truck. (*Le Génie Civil*, vol. 81, no. 23, Dec. 2, 1922, pp. 512–516, 9 figs., *d*)

An Improved Tube Rolling Mill

Improved Tube Rolling Mill. Abstract of British patent granted to R. E. Brock, an American. An interesting modification to the construction of tube rolling mills of the continuous type is described under this patent, the object being to secure more efficient operation in the manufacture of seamless tubing. In machines of this nature it is usual to pass the blank through a series of rolls in alignment with a gradually decreasing pass diameter, consecutive sets of rolls being arranged with the planes of maximum pressure perpendicular to one another. This, of course, results in a slight reduction in the diameter of the tube at each pass, with a corresponding elongation of the blank, so that the finished tube leaves the mill at a speed considerably greater than the speed at which the blank enters the opposite end. Actually, under average conditions the increase in speed is found to be approximately

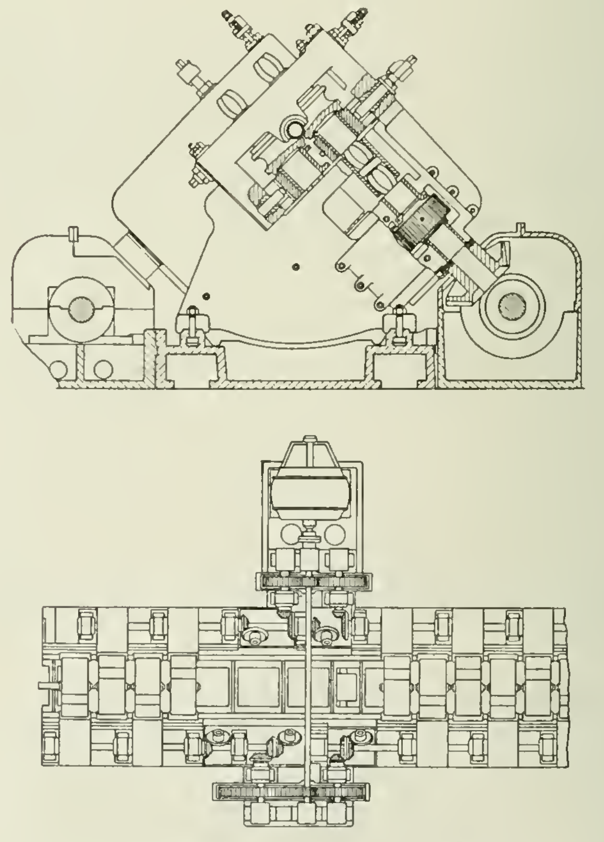


Fig. 7 An Improved Tube Rolling Mill

4 per cent at each pass, and it is to make allowance for this factor that the present improvement has been introduced.

Briefly, it consists in a particularly neat arrangement of the drive to each set of rolls, whereby a progressive increase of the speeds of the respective sets is obtained regardless of the speed of the primary driving shaft. The method of effecting this will be apparent from Fig. 7, which shows a part section through the mill in the

plane of the rolls, and a plan view from which the central sets of rolls has been omitted to show the drive.

It may be seen that the power is taken from a motor direct-coupled to a cross-shaft, which is fitted at either end with a pinion. Each of these pinions engages two spur gears, one on either side, while the spur gears are made with diameters progressively increasing, so that a corresponding range of speeds is obtained.

It may further be stated that the spur gears are keyed to short cross-shafts, each of which carries a bevel pinion at the inner end, and by this means the power is transmitted to four independent longitudinal shafts, which are thus driven at different speeds. The drive is then transmitted to each set of rolls by means of further bevel gears, arranged as shown in the upper view, and these members are also made so that the diameter increases progressively throughout the series. Thus, since alternate sets of rolls are driven from each longitudinal shaft, each pair may be driven at a speed approximately 4 per cent higher than the preceding set by suitably arranging the number of teeth in each bevel wheel.

In other respects the constructional features follow the usual practice with regard to rolling mills. (British Patent no. 185,543, abstracted through *Engineering Production*, vol. 5, no. 112, Nov. 23, 1922, pp. 501–502, 1 fig., *d*)

SPECIAL PROCESSES

Removal of Solid and Liquid Particles from Gases, A. F. Nesbit. Description of an apparatus of a type combining electrical and centrifugal action and intended chiefly for cleaning combustible gases such as coke-oven and blast-furnace gases to be used as a source of heat or motor fuel, though other gases may be similarly handled.

The apparatus may be purely mechanical or combined with certain electrical features. The purely mechanical cleaners do not remove as completely the dusts, tar, and other fogs constituting the recoverable contents of the gases as may be done by the use of combined electrical and mechanical cleaners, but they are free from the disadvantages always present when using electrical systems and they yield such a high percentage of recovery as to suggest a successful stage-refrigerating-type apparatus. (*Blast Furnace and Steel Plant*, vol. 10, no. 12, Dec., 1922, pp. 637–641, 5 figs., *d*)

TESTING AND MEASUREMENTS (See also Thermodynamics)

The Davon Microtelescope and Supermicroscope, F. Davidson. Description of two instruments invented by the author. As regards the microtelescope the principle involved is the application of a short-focus telescope objective in a tube with a series of diaphragms to the microscope, the microscope itself acting as a compound eyepiece. With that attachment, which contained a 6-in. telescope objective inserted into the Abbé rim of the microscope, there was an image of a distant object projected to the plane of the stage; the air image was magnified by the microscope proper and as a result objects could be seen as near as 6 ft. Its range was practically from 6 ft. to infinity. One could then, for example, view the scales of pyrometers or thermometers at any distance, inaccessible parts of machinery, and certain parts of a mine, provided, of course, that the light could be projected on to the object.

One of the characteristics of the observations with this instrument was depth of focus. One could look at an ordinary photograph with the instrument and see it in apparent stereoscopic relief. As an illustration of what can be done with the microtelescope, the author cites the case of a bird's nest which was photographed with this instrument at a distance of 50 yd.

Next, a short-focus attachment was provided for working with objects which, because of their size or shape, could not be put upon the stage of a microscope, for example, minerals, metal fractures, etc. Here a variation of magnification of from 30 to 90 diameters was possible without altering anything but the distance from the object, and even at the higher magnification the relative depth of focus was always maintained.

A third attachment was then provided, namely, another tube in which a microscope objective was placed at one end. At the other end of the tube was another achromatic combination, which the inventor called a collector. This gave the supermicroscope. By means of the collector the image of a microscopic object was projected at some distance beyond it. The position of the air image which was projected depended upon the distance that the collector happened to be from the front of the primary objective. This enabled them to carry the system of direct observation which was begun with a short-focus attachment up to very nearly 1000 diameters and still have sufficient working distance to eliminate an object from above.

It is of interest to note that anything that could be seen with either piece of apparatus could be photographed by it by simply removing the body tube of the microscope and substituting a camera. The same lens was used for telephotography as for observation. With a short attachment it was possible to photograph metal fractures and similar things, and with the supermicroscope the author photographed objects from life size to diatoms under a magnification of 3000 diameters. (*Chemical News*, vol. 125, no. 3270, Dec. 15, 1922, pp. 353–355, see also *Bulletin* of the Institution of Mining and Metallurgy, no. 218, Nov., 1922, pp. 1–5, *d*)

THERMODYNAMICS

Heat Transmission—Heat Measurements—Room Thermometers

New Methods and Investigations for Determining Heat Transmission, Prof. Oscar Knoblauch. Discussion of the meaning of the various coefficients of heat transmission and methods for their determination, including methods of measuring the temperature of the various elements entering into the problem.

The author devotes particular attention to the determination of the coefficient of heat transmission α which is the heat lost per unit area, say, 1 sq. m., of a surface, such as the wall of a building, to the ambient medium, such as air, per unit of time per hour per degree (centigrade) temperature difference. The great difficulty in determining this coefficient lies in the exact measurement of the air and wall temperatures.

In particular, as regards the measurement of air temperature, this should be measured in fairly close proximity to the wall. The difficulty of doing this, however, lies in the fact that if the thermometer is placed close to the wall, its reading may be materially affected by radiation losses, the direction of which would depend on whether the wall is colder or warmer than the thermometer. In the former case the thermometer would be losing heat by radiation to the wall and would show less than the true air temperature. In the latter case it would gain heat from the wall and would show an air temperature higher than the wall.

Experiments recently carried out by H. Hausen in Germany show that this error in thermometer reading may be quite material. All attempts to obviate this by such means as enclosing the thermometer in a metal sheath or using a rapidly moving thermometer or blowing the air over the thermometer and the like, are unsuitable for this particular purpose because they materially modify the conditions of the experiment.

Theoretically, the error in measurement due to the error of absorbed radiated heat may be considerably reduced by providing a thermometer with a surface of proper characteristics, namely, one that will absorb as little light and heat radiation as possible. The glass tube usual in mercury thermometers allows the majority of light rays to pass through, which therefore reach the mercury and are reflected by it. On the other hand, however, the glass absorbs powerfully the shorter-wave heat radiation and thereby contributes to the error in measurement discussed above. Since, however, gold and silver absorb only 2 per cent and nickel 5 per cent of the heat radiation, a substantial reduction in error due to heat absorption may be brought about by gilding, silvering, or nickeling the thermometer tube. If gold and silver are selected the error in measurement falls to about 3 per cent of the error of a thermometer with a plain glass tube, and this may be safely neglected in the majority of practical applications.

For measurements of precision, however, the readings of a thermometer even with the gilt and silver tube, are not sufficiently exact. There is, however, a way of obtaining an extremely exact reading by using two thermometers having tubes of different heat-absorption capacity, for example, one of plain glass and the other

gilt. In this case the true temperature of air t_0 may be expressed as—

$$t_0 = t' - K\,(t'' - t')$$

where t' is the reading of the thermometer with the gilt tube; K a coefficient depending on the constants of the two thermometers (in this case 0.15); and t'' the reading of thermometer with the higher heat absorption, as, for example, the plain glass tube.

If, for example, with such a double-thermometer outfit the glass-tube thermometer reads 23.0 deg. cent. and the gilt tube 20.0 deg., then the true temperature of the air t according to the above equation is—

$$t = 20 - 0.15\,(23 - 20) = 19.55 \text{ deg. cent.}$$

If such a double-thermometer outfit is suspended near a *cold* wall the temperature of the gilt-tube thermometer will be higher than that of the glass-tube thermometer and the temperature of both will be lower than the air temperature, all this being due to the loss of heat from the thermometers to the wall by radiation.

From this the author proceeds to the discussion of the ordinary method of measuring room temperature by means of a thermometer suspended on the wall. He finds that with the usual construction such a thermometer reads the room temperature fairly closely only where the room is so heated that it is maintained at a fairly constant temperature for a length of time sufficient for a fairly close equalization between air and wall temperature to be obtained. However, where the room is not heated for a greater part of the day and is only supplied with considerable amounts of heat for comparatively short intervals, so that the walls are not fairly cold, the temperature readings of a thermometer hung on a wall are extremely misleading. This is particularly so as the mercury bulb is enclosed in a wooden frame, and in addition is covered by perforated metal. Free contact with air is therefore materially precluded, while heat transfer between the wall and thermometer by conduction and radiation are encouraged. Such a thermometer is more suitable for measuring the wall temperature than the air temperature.

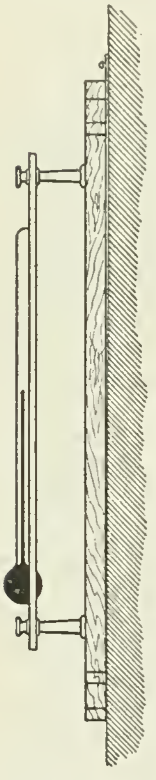


Fig. 8 The J. Greiner Wall Thermometer

A German concern is building a wall thermometer of the type shown in Fig. 8. Here the thermometer is supported on a wooden base suspended on the wall in the usual manner, but it is placed not in the base itself but on a milk-glass scale about 2 cm. (0.8 in.) from the wooden base. The mercury bulb is therefore freely in contact with the air while the wooden base protects the thermometer against a large share of heat radiation interchanged between it and the wall.

At the same time it is a question which of the two types of wall thermometer referred to above gives indications of greater practical interest. The human body in a room is subject to two kinds of temperature interchanges: namely, between the body and the air, and by radiation between the body and the walls. Where the room is rapidly heated up there may be a feeling of chill in a room where the true air temperature is as high as 68 deg., provided the wall temperature is low, and the latter may be as low as 50 deg. From this point of view a thermometer exposed to radiation losses to the wall loses more than one that is not so exposed, and, for example, under the above air and wall conditions a thermometer in a room having a true air temperature of 20 deg. cent. (68 deg. fahr.) will read only 17.3 deg. cent. (63 deg. fahr.).

The next problem which the author discusses is the measurement of the true wall temperature, which means the temperature of the surface of the wall exposed to the air. Here thermocouples present a sufficiently reliable means.

The author proceeds next to the discussion of methods for determining the heat transmission through walls of various tubes, hollow or solid, by means of numerical calculations, and shows that these have been developed to such an extent as to give results sufficiently reliable for all practical purposes. He points out also that of late a good deal more attention has been paid than formerly to the ability of walls to resist heat losses because of the greater cost and scarcity of fuel.

An extensive discussion of heat losses through windows concludes the article. In this case the author considers losses due both to heat flow through the window materials and air leakage due to lack of tightness in the window joints. In this connection extensive experiments made in Germany are quoted. (Paper before the annual meeting of the German Refrigerating Society, Munich, July 18, 1922, abstracted through *Zeitschrift für die Gesamte Kaelte-Industrie*, vol. 29, no. 10, Oct., 1922, pp. 177–183, 7 figs., *eg*)

VARIA

Industrial Situation in Japan. Data taken from a report by Sir E. T. F. Crowe and G. B. Sansom of Tokyo, issued by the British Department of Overseas Trade and dealing with the commercial, industrial, and financial situation in Japan during 1921 and up to June 30, 1922.

From this report it would appear that contrary to the common impression Japan is a country of high production costs. This is illustrated in the case of copper. Japan is one of the largest producers of copper in the world. Before the war her output averaged 60,000 tons a year, and next to silk and cotton yarns copper was the most important export. The principal mines were owned by a few of the richest families of the country and the copper business was looked upon as being very prosperous and profitable. In 1919 and 1920 for the first time copper began to be imported as consumption increased, while production fell off owing to increased costs. The imports fell off in 1921 but increased again in 1922. The copper-mine owners declared that they were unable to produce copper at a price which could compete with the imports from America, and the government, in order to protect an important domestic industry, accordingly increased the duty from 0.20 yen per 100 kin to 7 yen. For a short period imports ceased, but last June they were again beginning to come in.

It is estimated that the consumption of copper in Japan is about 6000 tons a month, while production has dropped below 5000 tons. In 1917 Japan produced on an average 10,000 tons monthly. The problem facing the mine owners is whether to attempt to produce more economically and meet competition or to maintain the price at a high level by reducing output.

The latter uneconomic policy has been followed by the colliery owners who curtailed output by $17^1/_2$ per cent in order to bolster up prices. It is this tendency, the report points out, of continually forcing up prices and preventing them from finding their natural level which must seriously damage Japanese trade unless it is remedied in time. The immediate effect has naturally been to keep the cost of living at the high level to which it mounted during the war.

As regards the iron and steel industries, it was pointed out in another report that Japan has made rapid strides in its wire-manufacturing industry and today is turning out wire rope, plain wire, and wire nails of good quality. The production of these commodities, however, is not sufficient to meet the needs of the Japanese, resulting in heavy purchases of foreign wire goods. The demand for wire products is principally in galvanized plain and bright wire and wire nails. To a less extent there is a call for wire rope and cable, insulated wire and cable, woven wire fencing, wire cloth and screening.

Boiler plates for the Japanese-made locomotive, war vessel, steamship, and other equipment are largely imported. In May, 1922, 1839 tons of boiler plates and 2189 tons of other steel plates of American manufacture were taken by the Japanese. (*The Electrical Review*, vol. 91, no. 2344, Oct. 27, 1922, pp. 605–606, *g*)

CLASSIFICATON OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general, *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Progress in the Art of Power Development

By A. G. Christie,[1] Baltimore, Md.

The Power Division concerns itself with all problems involved in the generation and transmission of power. Among the more important problems are those concerning the development of underlying theory, the design, construction, and operation of all classes of power machinery, both steam and hydraulic, the transmission and distribution of power, and economic questions concerning power development.

Since the greater portion of our power supply is developed from steam at the present time, much attention has been devoted to factors concerning the design and construction of steam stations. The increased costs of fuel and of labor have had a very material affect on plant design. Emphasis is now placed on the operation of the plant as a whole rather than on prime mover or boiler alone. This has led to careful study of the heat balance of the complete plant. Such studies often develop possibilities for improvements and have a very stimulating effect on the management. In new designs much thought is devoted to heat-balance studies of various schemes before a final selection is made. Minor heat losses such as those in the generator cooling air, transformer losses, bearing losses, and gland leakage are now being recovered and utilized. Systems of operating auxilaries to secure the lowest B.t.u. per kw-hr. of net station output are being developed which differ radically from former practice. In some cases house turbines are employed with motors on all auxiliaries. These, however, will probably be omitted from future stations where economizers are not used and all power for auxiliaries will be furnished from the main turbines which will be of the multiple bleeder type. Certain of the essential auxiliaries will be equipped with synchronous motors and a duplex steam drive in reserve that will pick up load in an emergency and will operate certain other auxiliaries with the synchronous motor acting as a generator.

Substantial progress is being made both in size and in designs of large turbo-generators. Types built under the stress of war conditions developed certain weaknesses, and as a result all the large companies both here and abroad have been redesigning and improving their machines. The newer designs are more compact and better built. The ideal turbine will provide the steam with the smoothest and most direct expanding passages free from sudden changes in cross-section or in direction, and with stationary and revolving guides or buckets whose curved surfaces offer the minimum of shock to the high-velocity steam. This ideal is being approached in recent designs. A uniform distribution of steam in the exhaust pipe and the utilization of the velocity energy leaving the blades are also attempted in some of the new units.

Multi-stage bleeding is becoming standard practice with large steam turbines. Engineers will soon demand that the builders themselves provide the turbine and bleeders and base all guarantees on the performance of the unit as a whole, resulting in better design and improved thermodynamic performance.

The characteristics and limitations of small steam turbines are becoming better known. New designs embody substantial improvement over earlier types. There is still need for further improvement in these units intended for auxiliary service. Small steam turbines have not been able to compete on the basis of economy with uniflow engines.

There is a decided tendency at the present time to increase steam pressures and temperatures. Mr. Orrok has ably discussed this subject in his recent paper on The Commercial Economy of High Pressure and High Superheat in the Central Station. He concludes that 1200 to 1500 lb. steam pressure is commercial but that temperatures are limited to about 750 deg. fahr. until better materials can be developed for valves and piping. The Benson system now being considered in Great Britain goes to pressures in the neighborhood of 3200 lb. per sq. in., but while sound theoretically has not been commercialized. Recent announcement of plants to use 550 lb. pressure seem to indicate conservative design as far as ultimate limitations are concerned.

Mr. Orrok pointed out that most of our discussions on high pressures and temperatures are academic in view of the lack of definite knowledge of the properties of steam under these conditions. The Steam Table Research when completed will be of inestimable value to engineers. Much discussion of the so-called "supersaturation" state of steam has developed in England. American engineers desire to be further enlightened on this subject, which up to the present time has not received much attention in this country.

The steam boiler and it auxiliaries are prime essentials in power generation. Boilers are steadily increasing in size and height. The Power Division has directed its attention to a study of heat absorption in boilers, and this is progressing satisfactorily under the direction of Mr. E. B. Powell. It is hoped that an early report can be made to the Division. The introduction of powdered fuel with increasing furnace temperatures has made the employment of water screens necessary and has suggested the use of radiant-energy superheaters in the side walls. The influence on furnace temperature of these added heat-absorbing surfaces will be watched with great interest, and will have considerable effect on future furnace design.

Boilers are now operated for varying periods at high ratings. This can only be done where the tube surfaces are free from scale and the feedwater free from foaming alkalis. Hence the feedwater must be kept pure. Many stations now employ evaporated make-up. If low-priced evaporators were available in small sizes it would be advisable to furnish distilled make-up for feedwater in a great many of our small plants where only impregnated water is available.

Rising coal prices have resulted in the wider adoption of economizers, which in high-pressure plants have steel tubes. Several new problems have been presented to engineers by the adoption of these steel tubes. In the first place corrosion is very rapid and very destructive if any oxygen remains in solution in the feedwater. Hence various methods and equipment have been devised to deaërate the feedwater. Difficulty with corrosion of the outside of economizer tubes has been encountered where coals high in sulphur are used. A study of the dewpoints of sulphur compounds may reveal the cause of this difficulty.

In plant economy the B.t.u. per kw-hr. developed has been steadily reduced and will be further lowered when some of the newer ideas on heat balance have been fully developed.

There is a wide interest nationally in the development of water power, and many new undertakings are being planned. Engineers have devoted their attention to the development of turbines of increasing size for large power developments and to new designs to operate efficiently under low heads. Definite progress has been made in improving the overall efficiency of turbines by the use of the hydraucone, the improved draft tube, and the regainer. Several of these developments have been discussed at meetings under the auspices of the Power Division and papers on new developments are planned for coming meetings.

Reduction gears produced during the urgency of the war period were in many cases not of the best materials nor carefully made. Gears of recent manufacture have been greatly improved and are now regarded as standard equipment for many purposes.

The increased interest being given to the question of conservation of the valuable products of coal and to the low-temperature carbonization process should make power engineers give some thought to the ultimate plant of the future. A scheme is already under consideration for at least one large station where a low-temperature carbonization process adjoining the steam plant will furnish rich gas to the city mains for domestic purposes and a low-volatile coke that burns without smoke for heating purposes. This semi-coke in pulverized form will serve as the fuel supply to the boiler furnaces of the electric plant. The motor fuels, alcohol, creosote, fuel oils, ammonium sulphate, and other valuable by-products will be available for sale. In the near future the power engineer may have to be a gas-house man as well as a steam-station expert if the present tendency continues.

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[1] Professor of mechanical engineering, Johns Hopkins University. Retiring Chairman Power Division, A.S.M.E.

ENGINEERING RESEARCH

A Department Conducted by the Research Committee of the A.S.M.E.

Personnel Methods—Recognition and Classification of Human Abilities

DURING the last decade there has grown up in industry a new branch of technology that has received the appropriate descriptive name of "human engineering." The development has come about through an increasing demand for means to assist managers in selecting men better suited, from the points of view of employee and of employer, to the work they have to do. There is wide demand for reliable information about the methods which have appeared in the form of mental tests, trade tests, rating scales, and other means of discovering human qualifications.

Standardized tests and measurements are widely sought by engineers, but the hazards incident to the activities of charlatans prevent the full utilization of this contribution of modern science. Recognizing the importance of the movement and the need for careful scientific appraisal of available methods, the National Research Council has initiated various activities for the benefit of managers who are dealing with human problems. To this end the Research Information Service of the Council is giving attention to the compilation of reliable information about personnel matters.

As a free clearing house for the promotion of research and its applications in industry, the Research Information Service is prepared to furnish critical information about modern personnel methods. Among the mechanisms especially designed for this informational service there is maintained a personnel file in which consulting psychologists, personnel specialists, and other reputable experts on problems of human adjustment are listed. Files of information about available tests and their particular usefulness are also maintained.

With specialists on these problems in the Council offices and with files of information at their disposal, mechanical engineers may profitably appeal to the Research Information Service for facts about methods of personnel classification. All communications should be addresses to Research Information Service, National Research Council, Washnington, D. C.

Research Résumé of the Month

A—Research Results

Explosives and Explosions A1-23. Study of Explosions of Gaseous Mixtures. The immediate object of the series of tests reported in the most recent Bulletin (No. 133) of the Engineering Experiment Station of the University of Illinois was a study of the physical phenomena involved in the explosions of various mixtures of illuminating gas and air. Prof. A. P. Kratz and Mr. C. Z. Rosecrans are the authors. The bulletin includes the determination of the effect of different-shaped explosion vessels, and of turbulence at the time of ignition, as well as a study of the heat loss from the burning mass of gas. Any problems connected with the chemical changes involved have not been considered within the scope of the investigation.

An investigation of explosions of gaseous mixtures at constant volume was undertaken by the Engineering Experiment Station in 1914, when C. R. Richards outlined an extensive series of experiments and defined the scope of the investigation which was to follow. Apparatus was designed and a few results were obtained showing the effect of the shape of the explosion vessel and of turbulence at the time of firing, but it was found necessary to discontinue the work. In 1919 part of the apparatus was redesigned and work was resumed. This bulletin is a preliminary report of the methods pursued and the results thus far obtained.

Address the authors in care of the University of Illinois, Engineering Experiment Station, Urbana, Illinois.

Gases, A1-23. Study of Explosions of Gaseous Mixtures. See *Explosives and Explosions A1-23.*

B—Research in Progress

Ceramics and Glass B1-23. Influence of Burning Fuel Oil on Refractories. See *Refractories B1-23.*

Fluid Flow B1-23. Flow of Water in Vertical Pipes. A considerable amount of laboratory work has been completed in an investigation of the possible rates of flow through vertical pipes. This study is being conducted at the University of Illinois by Mr. W. J. Putnam and is to include work on pipe of various lengths and with different entrance conditions. The pipes discharge into the air in all cases and the tests, therefore, apply to flow through down spouts, drains, industrial piping systems, etc.

Framed Structures B1-23. Stresses in Statically Interminate Frames. Bulletin No. 108 of the University of Illinois issued in 1918 presents equations for moments in frames due to any type of load. The work which Mr. W. M. Wilson has completed during the past year on this subject consists of the derivation of the corresponding equations for the stresses due to particular loads. This material will be published shortly as one section of the Structural Engineer's Handbook Library.

Framed Structures B2-23. Web Stresses in Beams. A study of the effect of spacing of stirrups and a comparison between the actions of rectangular and T-beams is now being made under the direction of Prof. A. N. Talbot at the University of Illinois. During the past year tests on 20 large rectangular and T-beams have been completed.

Gas, B1-23. Efficiency in Gas Combustion. An investigation has been recently undertaken by Mr. F. E. Vandaveer at the Engineeiing Experiment Station of the University of Illinois to determine the possible extensions in the use of fuel gas in the industries. As this study progresses it is proposed to take up (*a*) the catalytic chamber, (*b*) thorough mixing of air and gas, and (*c*) the effect of temperature at time of combustion.

Gases, B2-23. Amount of Water in a Nearly Dry Gas. An electrical device for detecting and approximately indicating the amount of water in a nearly dry gas, upon which a considerable amount of work was done several years ago at the Bureau of Standards, has been again tried out with surprisingly good results. The detector appears to have lost none of its sensitivity during nearly three years in the laboratory. This would indicate that it may be relied upon as an alarm device in the liquefaction and nitrogen-fixation industries where such a device is greatly needed. The Bureau hopes to prepare and publish a description of the device in the near future.

Mechanics, B1-23. Web Stresses in Beams. See *Framed Structures B2-23.*

Mechanics, B2-23. Fatigue of Metals. Bulletin No. 124 of the University of Illinois describing this important investigation by Professors Moore and Kommers was mentioned in these columns in the February, 1922, issue. It is now possible to announce that a second bulletin by the same authors is in preparation which will describe new tests of materials under a combination of steady tension and reverse bending and also under reversals of direct axial stress.

Non-Ferrous Metals B1-23. Contraction and Shrinkage of Non-Ferrous Alloys as Related to Casting Practice. One of the fundamental problems under investigation by the Bureau of Mines in its alloy work is the contraction of a series of light aluminum alloys, particulars of which will soon be published as Bulletin 287 of the Bureau. An investigation is now under way on the contraction of a series of commercial brasses and bronzes.

While the contraction of alloys is only one of the factors that bear on cracks in castings, as well as on the casting qualities of any alloy, still it is important; and comparative figures as to the contraction of various alloys will serve as a guide to their casting qualities and cracking tendency.

A "Report of Investigation" Serial No. 2410 prepared by Mr. Robert J. Anderson is a short discussion of the technical aspects of contraction in relation to foundry practice, and has been published in response to numerous inquiries for information, with the recommendation of the Advisory Committee.

On the basis of the available information, the following conclusions may be drawn as to the contraction and shrinkage of alloys as related to foundry practice:

1 The linear contraction of any alloy is a function of the exact chemical composition of that alloy, and relatively small amounts of impurities affect the contraction.

2 The wide variation in contraction among the alloys of a given class—for example, brasses, bronzes, or aluminum alloys—indicates that it is poor practice to employ a rough figure as the contraction of alloys of a given class in general, since by so doing much difficulty arises in producing master patterns and in obtaining castings with a minimum of wasters.

3 Theoretically, the higher the pouring temperature the greater the contraction, as less metal can be held in a mold cavity at a higher temperature than at a lower temperature. Actually, pouring at an intermediate temperature gives greater contraction than pouring at a high temperature or a low temperature on account of the effect of gas evolution in the case of alloys poured at high temperatures. The evo-

lution of gas referred to causes actual expansion, thus interfering with normal contraction and yielding less contraction.

4 Other things being equal, the smaller the cross-section, the less the contraction for a given length.

5 Other conditions being the same, the greater the length for a given cross-section the less the contraction.

6 The linear contraction of alloys is a function of the kind of mold employed, the contraction being greater in chill molds than in sand molds, other conditions being the same.

7 In sand molds the contraction in a casting depends upon the contour of the pattern, the mass of the casting, and the size and distribution of the gates and risers—that is, the method of molding.

8 Gas occlusion, owing to a high melting temperature, causes less contraction owing to evolution of the gas when the metal freezes.

9 The extent to which piping occurs on casting an alloy in an open-top ingot mold is a factor in determining the suitability of an alloy for casting purposes, as this is an indication of the contraction in volume. In general, the less the depth of pipe, the less the contraction in volume.

Railroad Rolling Stock and Accessories B1-23. Action of Exhaust Jet in Front End of Steam Locomotives. This investigation has been undertaken at the University of Illinois by Prof. J. M. Snodgrass to determine the action of the exhaust jet in producing draft. The study will seek to determine the influence upon draft of exhaust steam pressure and volume, jet velocity, and form of jet nozzle. It is intended to begin this work by means of a small model so constructed as to permit visual observations of the actions within the front end as well as the usual observations for draft, steam pressure, etc. Any conclusions or generalizations arising from work with the model will be checked on the locomotive in the laboratory, and possibly in road tests.

Railroad Rolling Stock and Accessories B2-23. Tractive Effort of Steam Locomotives Tests for the accumulation of additional experimental data are now in progress, being conducted jointly by the Illinois Central Railroad and the University of Illinois. The specific object for this investigation is the determination of a method for predicting the tractive effort of locomotives, knowing their dimensions and principal operating conditions. Address Edward C. Schmidt, care of the University.

Refractories B2-22. Study of Electric-Furnace Refractories. As the development of refractories for electric furnaces is now being undertaken, it is desirable to have a method and apparatus for measuring their conductivity at advanced temperatures, states the Federal Bureau of Mines. Moreover, data in regard to the conductivity of existing refractories at temperatures above 1400 deg. cent. are meager. It is proposed to study the leakage factor through refractories. The method of attack has been worked out and the furnace designed, the material for which is arriving at the U. S. Bureau of Mines ceramic experiment station at Columbus, Ohio.

Steel B1-23. Gage Steels. Progress reports on the work so far done by the Gage Steel Committee were considered at the meeting held in New York on November 17th and a program outlined for continuing the work. The samples of a steel selected by the committee for investigation have been received and preliminary work is well under way. Dimensional changes on hardening and changes with time after hardening are being studied; also the rate of wear of different specimens which have been subjected to various heat treatments.

C—Research Problems

Framed Structures C1-23. Strength and Action of Bolted and Riveted Connections. A number of companies interested in this investigation have supplied the University of Illinois with a considerable amount of material with which to begin work. Professors A. N. Talbot and A. F. Moore are to undertake this study as soon as the necessary assistants and machines are available.

F—Bibliographies

Explosions and Explosives F1-23. Gaseous Explosions. This bibliography contains references, not only on the subject of the physical phenomena involved in the explosions of gaseous mixtures but also in regard to the chemical transformations and other allied phenomena. Numerous references of a mathematical nature, particularly in regard to the subject of explosion waves, are also included, as well as some few references describing instruments and apparatus used in investigations of gaseous explosions. It consists of twenty-one closely printed 6 by 9-in. pages and forms Appendix C of the University of Illinois Bulletin No. 133.

Gases F1-23. Gaseous Explosions. See *Explosions and Explosives F1-23.*

Highways F1-23. Projects in Highway Research Current or Recently Completed. The October, 1922, Bulletin of the National Research Council is devoted entirely to a report on the Census which the Advisory Board on Highway Research recently completed. In Part IV, 479 research projects in highway engineering and highway transport are listed and briefly described. These projects are listed under the following five main headings: Economics, Operation, Design, Construction, and Material. Address The National Academy of Sciences Washington, D. C.

Road Materials and Equipment F1-23. Projects in Highway Research Current or Recently Completed. See *Highways F1-23.*

Framed Structures F1-23. Riveted Joints. The literature on this subject both European and American has been very carefully listed and briefly abstracted by Dr. A. H. Stang, connected with the Structural and Engineering Materials Section of the Bureau of Standards. It consists of twenty-six closely typewritten pages. Address Bureau of Standards, Washington, D. C.

Progress Report of A.S.M.E. Research Committee on Fluid Meters

After years of effort on the part of the Research Committee on Fluid Meters of The American Society of Mechanical Engineers, its report is complete and will be issued in pamphlet form within a few weeks.

This report takes the form of a reference book on flow meters of all kinds. It contains not only such practical instruction and information, including formulas, constants, etc., as may be needed by the actual or prospective user, but also more general information —the physical principles of design and operation—which may be useful to students, designing engineers, and inventors.

Part I treats the general types of flow meters as well as the principles and methods involved and gives information which may, in many cases, be applicable to various commercial meters. In this part individual makes of instruments are not discussed in detail, but are referred to only incidentally or for illustrative purposes. The general physical principles are in the body of the text, while the derivation of formulas and the refinements of the theory involved have been placed in the appendices which accompany the report.

In Part II will be found more detailed information concerning the practical use of all the flow meters now in common use. This information has been obtained from both users and makers and includes descriptions of commercial meters, and particulars with respect to operating characteristics, influence of installation, and the testing of meters.

Flow meters are of great and rapidly increasing importance, but hitherto the information available on this group of instruments has been incomplete. The material forming Chapters 1, 2, 3, 4, 5, 6, and Appendix C, were recently rewritten. This material contains a new presentation of the subject based on a mathematical analysis which is more specifically applicable to fluid flow than Bernoulli's theorem. The analysis did not include the additional experimental data now given in the report, but these data required no serious modification of the text.

The most important modern advance in experimental aerodynamics and hydraulics is the application to them of dimensional analysis. This is absolutely indispensable to an understanding of the behavior of moving fluids, for the phenomena of fluid motion are so complicated as to defy analysis by any other known method. The use of this method is especially valuable, in that it makes possible the reconciliation of data obtained from experiments with the venturi tube and the thin-disk orifice which were formerly thought to be irreconcilable. These data are now shown to be mutually confirmatory.

A few of the chapter heads will serve to indicate the scope of the material covered by this report: Classification of Fluid Meters, Weighing Meters, Volumeters, Current Meters, Head Meters including General Principles, Venturi Meters, Flow Nozzle, Thin-Plate Orifice, Pitot Tube, Area Meters, Force Meters, and Thermal Meters.

The Report was prepared and signed by the following men who constitute this special Research Committee on Fluid Meters: Messrs. R. J. S. Pigott, Chairman, J. M. Spitzglass, Secretary, E. G. Bailey, L. L. Borden, G. S. Coffin, A. R. Dodge, L. M. Goldsmith, F. G. Hechler, Horace Judd, Leo Loeb, P. S. Lyon, W. Maplesden, H. N. Packard and C. G. Richardson.

Those desiring copies of this report should address the Secretary, care of The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y.

CORRESPONDENCE

CONTRIBUTIONS to the Correspondence Department of MECHANICAL ENGINEERING are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities and policies of the Society in Research and Standardization.

Mathematical Determination of the Modulus of Elasticity

TO THE EDITOR:

The letter in the December issue of MECHANICAL ENGINEERING from Mr. David Guelbaum, entitled Mathematical Determination of the Modulus of Elasticity, is a very interesting deduction from what is commonly known as the general equation of the elastic curve. It should be noted, however, that while a high degree of precision is claimed for the method and that while the derivation of the equations is mathematically correct, Mr. Guelbaum has apparently ignored the fact that he started with a formula which has decided limitations. The general equation of the elastic curve which states that the bending moment at any section of a bent bar is equal to the modulus of elasticity of the material multiplied by the moment of inertia of the section and divided by the radius of curvature at that section ($M = EI/\rho$), depends for its derivation on the assumption that the radius of curvature is practically infinite. This is far from being the case in the use of Mr. Guelbaum's method.

The equations derived and the mechanical device suggested may prove useful for approximate results where no testing machine is available, but I doubt very much the possibility of attaining the degree of accuracy with this device that is attained with the ordinary testing-machine method.

New York, N. Y. WM. R. BRYANS.

The Entropy of Saturated Steam: Its Relation to Specific Volume

TO THE EDITOR:

The object of this communication is to call attention to what appears to be a remarkable relation between the entropy of saturated steam and its specific volume. While the total entropy of the steam from water at 32 deg. fahr. cannot be calculated directly from the specific volume, if this quantity is determined for one temperature and pressure, then the entropy for all other temperatures and pressures can be calculated from the respective volumes, without the use of other data.

If V_0 and s_0 represent respectively the specific volume and the known entropy of saturated steam of any pressure; V_1 and s_1 the specific volume and entropy of steam at some higher pressure; and if V_2 and s_2 the same quantities at some lower pressure; then—

$$s_1 = s_0 - \phi\,(\log V_0 - \log V_1) \qquad [1]$$

$$s_2 = s_0 + \phi\,(\log V_2 - \log V_0) \qquad [2]$$

If the common system of logarithms is used, $\phi = {}^1/_5 = 0.2$.

In the examples which follow, values for V and s are taken from Goodenough's steam tables, 1915 edition. Steam at atmospheric pressure has been selected for the starting point of the calculations, on the assumption that our experimental knowledge of the properties of steam is probably more exact for that pressure than for other pressures. Therefore—

$$V_0 = 26.81 \text{ cu. ft.}$$
$$\log V_0 = 1.4282968$$
$$s_0 = 1.7589$$

For steam at 300 lb. pressure,

$$V_1 = 1.545 \text{ cu. ft.}$$
$$\log V_1 = 0.1889285$$

From Equation [1],

$$s_1 = 1.7589 - 0.2\,(1.4282968 - 0.1889285) = 1.5110$$

The entropy of steam at 300 lb. pressure in Goodenough's tables is 1.5092. The calculated value of 1.5110, while ${}^1/_{839}$ larger than the tabulated value, is smaller than the value assigned by Marks and Davis or by Peabody.

For steam at 1 lb. pressure,

$$V_2 = 333.3 \text{ cu. ft.}$$
$$\log V_2 = 2.5228353$$

From Equation [2],

$$s_2 = 1.7589 + 0.2(2.5228353 - 1.4282968) = 1.9778$$

The value given in Goodenough's tables is 1.9775, which is practically identical.

Table 1 gives the entropies as calculated by Equations [1] and [2] for several intermediate pressures between the extremes of 300 lb. and 1 lb., as well as the corresponding values given in the standard steam tables of Goodenough, Peabody, and Marks and Davis. It will be observed that wherever the calculated values differ appreciably from the tabular values of Goodenough, they lie between the values of Goodenough and those of the other authorities.

TABLE 1 VOLUME AND ENTROPY OF SATURATED STEAM

Absolute pressure, lb.	Volume, cu. ft.	—Total Entropy from 32 Deg. Fahr. According to— Eq. [1] and [2]	Goodenough	Peabody	Marks and Davis
300	1.545	1.5110	1.5092	1.5130	1.5129
200	2.292	1.5453	1.5456	1.5459	1.5456
125	3.593	1.5843	1.5858	1.5840	1.5839
50	8.53	1.6594	1.6601	1.6581	1.6581
14.7	26.81	....	1.7589	1.7566	1.7565
5	73.5	1.8465	1.8456	1.8435	1.8432
1	333.3	1.9778	1.9775	1.9762	1.9754

A study of reversible heat changes in a theoretically perfect gas indicates very emphatically a direct relation between change of volume and change of entropy. For example, if a perfect gas having the characteristics of air at ordinary pressures and temperatures—the constant value of PV being $53.35T$—be expanded from V_a to V_b by any reversible heat process, the initial and final temperatures being the same, the numerical value of the increase of entropy will be equal to—

$$\frac{1}{6^1/_3}\left(\log_{10}\frac{V_b}{V_a}\right)$$

In attempting to establish a similar relation in the case of a saturated vapor it was thought that since the change of volume occurred only during the process of vaporization, the direct relation would exist between the volume and the entropy of *vaporization*. After failing hopelessly to establish this apparently logical relation, it was found, by taking a seemingly forlorn chance, that the total entropy must be considered—i.e., the increase of entropy from the beginning of the liquid stage—until the transformation into a saturated vapor is complete. This indicates that the so-called "heat of the liquid" plays its part in increasing the volume of the fluid when the opportunity presents itself.

It is interesting to note that in the entropy calculations described the factors of heat and temperature are absent. Possibly they may enter indirectly through the volume ratios.

There may be a more exact value for ϕ—Equations [1] and [2]—than 0.2, but inasmuch as it gives results differing from those of recognized authorities less than these authorities differ from each other, its convenience justifies its use.

There are indications that some similar relation may exist between the volume and the entropy of superheated steam, but it is perhaps not so simple and direct. The relation changes very abruptly and very substantially at the instant that the region of superheat is entered.

This volume-entropy relation was not evolved by any scientific

investigation. It is merely something on which the author stumbled accidentally, and which on examination looked interesting. It is passed along in the hope that it may suggest a new line of thought to some one who is skilled and experienced in research work of this general character.

Henry E. Longwell.

Eastwood, N. Y.

STRESSES IN ELECTRIC-RAILWAY MOTOR PINIONS

(Continued from page 95)

elastic method had predicted is to be found in the fact that beyond the elastic limit the stress-and-strain relation no longer follows Hooke's law. Therefore the stresses set up in the steel pinions by the shrinking process no longer correspond with those set up in the celluloid model.

While the flat shape of the break in Fig. 9 is one limiting case (torque without radial shrinking pressure), Fig. 8 may be considered as the other limiting case (radial shrinking pressure without torque), showing a V-shaped fracture for which the angle of the V has become equal to zero.

It may be concluded, then, that the inspection of the fracture may be a means of determining the cause of the failure. In this way, possibly, the responsibility may be established between builder and customer as regards pinion mounting.

The complete paper includes a detailed stress analysis which shows the comparative ease with which such a stress problem as the one dealt with can be handled by the photo-elastic method, whereas the use of ordinary engineering methods gives untrustworthy results and the exact mathematical solution based upon the theory of elasticity is impossible.

Acknowledgment is due to the Massachusetts Institute of Technology for permission to use in this article certain of the results included in the thesis submitted by Dr. Paul Heymans, University of Ghent, Belgium, as partial fulfilment of the requirements for the degree of Doctor of Science from the Institute.

Discussion

In opening the discussion, A. L. Kimball, Jr., one of the authors, stated that the importance of the investigation outlined in the paper lay mainly in the determination of perfections of pinion design as regarded stress. The similarity of celluloid to steel in the homogeneity of its elastic properties made it possible to study stress distribution in the celluloid models. Mr. Kimball stated that it was possible to study static stress distribution to gain information about stress due to impact as under both conditions the stress distributed itself in substantially the same way.

In answer to some questions asked by J. O. Madison,[1] Dr. Heymans stated that the celluloid models were mounted on steel shafts and that some of the differences in color indicating stresses in the models were due to variations in age of the celluloid used. Mr. Madison stated that in his practice railway pinions were forced on shafts by first boiling in water, putting them on hot and setting with a given number of blows of sledges of definite weights. E. O. Waters[2] emphasized the possibility of using the photo-elastic method to determine facts relating to stresses, pressure distribution, and wear. Dr. A. A. Adler[3] suggested the rotation of the celluloid models and the securing of pictures under actual operating conditions. He also emphasized the need for solving two-dimensional stresses before considering stresses in three-dimensions.

In this connection Dr. Heymans pointed out that in the three-dimensional elastic problem the stress distribution was not independent of the elastic constants of the material so that any determinations in celluloid might not be applied to other materials with different elastic characteristics.

In a written discussion received subsequent to the meeting Dr. S. Timoshenko[1] pointed out that the photo-elastic method of analysis of two-dimensional problems had a broad application within limits and it was important that these limitations be clearly understood. The method failed where the elastic limit of the material under test was exceeded. Dr. Timoshenko suggested that two observations be made by the authors, including the stress distribution from some external force acting on the tooth of the pinion and the stress distribution for similar pressure acting on the inner diameter. From these observations it was possible to obtain stresses at any point of the pinion by the vector sum provided the resultant stress lay within the elastic limit. He also pointed out that the presence of shafting would cause three dimensional stresses at the common boundary of pinion and shaft, rendering the photo-elastic method invalid. He also pointed out that in a study of the effect of pressure acting on the inner diameter it would have been valuable to have compared the pinion with a ring, the outer diameter of which was equal to the diameter at the root of the teeth.

In a plastic material, such was steel, it was impossible to foretell that a given section would prove weakest at the breaking point of the material, because this section contained the maximum stresses when the body was stressed within the elastic limits. Therefore, the photo-elastic results could not confirm any rupture tests on specimen. Moreover, no conclusions could be reached from the tests themselves. In all, only three were made and it seemed to him that on the basis of these alone, it was just as probable that the breaks through the thicker sections had been caused by the initial stresses in the materials as by the stresses produced by the applied forces.

The present paper would be of direct benefit to the designing engineer if, for any given tooth shape, it gave him a definite relation between the actual stresses across the "Minimum cross-section" of the tooth and those obtained by calculation from the cantilever formula. For example, taking the depth of the tooth above the cross-section considered as equal to $^1/_2$ in., the thickness equal to $^1/_3$ in. and the load at the end equal to 1500 lb., the maximum stress obtained from the cantilever formula would be

$$p_{max} = \frac{1500 \times {}^1/_2 \times 6}{\left(\frac{1}{3}\right)^2} = 40{,}500 \text{ lb. per sq. in.}$$

Comparing this with the stresses 72,600 and 80,000 given by the photo-elastic method, it would be seen that the increase of maximum stress due to the local stresses near the root of the tooth, over that given by the cantilever formula was respectively 79 per cent and 98 per cent.

[1] New York, N. Y.

[2] Asst. Prof. Machine Design, Yale University Jun. Mem. A.S M.E.

[3] Consulting Engineer, New York City Mem. Am.Soc.M.E.

[1] Consulting Engineer, Vibration Specialty Co., Philadelphia, Pa.

WORK OF THE A.S.M.E. BOILER CODE COMMITTEE

The Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and simultaneously published in Mechanical Engineering.

Below are given the interpretations of the Committee in Cases Nos. 408 to 410 inclusive, as formulated at the meeting of December 8, 1922, and approved by the Council. In accordance with the Committee's practice, the names of inquirers have been omitted.

Case No. 408

Inquiry: What thickness is required under Par. M-3 of the Code for Miniature Boilers for the plate forming heads which are not an

(Continued on page 149)

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities Papers and Proceedings of

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The Engineer of Tomorrow

Chas. F. Scott

Dean Kimball in his presidential address last month made a keen analysis of conditions prevailing in our modern life. He showed that the engineer has done his part in the past to bring about the civilization in which we live. The importance of the engineer in present activities was indicated, and he pointed out the larger sphere of action which the engineer should logically take in the future. In public affairs the military leader, the legal leader, and the business or financial leader must give way to the scientific or engineering leader.

Dean Kimball's statements have met with criticism and question. An editorial in a daily paper of one of our large industrial cities says that an engineer is a practical man who sees the things that need to be done and goes ahead and does them, but that he is not fitted temperamentally or by training for political positions of service.

What the engineer will be and what he will do depend upon the engineer himself. The engineering criterion of fitness and quality will be applied and if the engineer does play a leading part in the future, it will be because he is worthy of it.

What type of a man will the engineer of the future be? It is significant that the presidential address was delivered by one of our foremost engineering educators, by one who is directing a factory which is making engineers of the future. Whether his vision of a future in which the engineer will be a national leader will be realized will depend in large measure upon whether Dean Kimball himself and his associates in the engineering educational field are successful in giving men the training and the vision which will fit them for national leadership.

The engineer of tomorrow is the engineering student of today. The place which engineers will take in the future and the part they will play in solving the larger economic, social, and governmental problems which the spread of engineering has created, will depend upon how the engineering student of today develops into the engineer of tomorrow.

The importance of this matter is one which extends far beyond the schools themselves. Engineers, engineering societies, and society at large have a profound concern in the ideals and the training of the engineer. The Society for the Promotion of Engineering Education, of which Dean Kimball is a vice-president, has just organized a Board of Investigation and Coördination for the broad consideration of problems of this kind.

If engineers are to take an important place in the future of this country and of the world we may well ask that a survey be made of the number and type of engineers that will be needed. We should ascertain whether our schools are now equipped for producing the proper number of men of the right kind. If more are needed or if a different type of graduate is called for, then we must have more freshmen, and freshmen of a different type.

The members of this Board are M. E. Cooley, Past-President of the A.S.M.E.; F. W. McNair, President, Michigan College of Mines; D. C. Jackson, Massachusetts Institute of Technology; John H. Dunlap, Secretary, A.S.C.E., and C. F. Scott, Yale University. Dean Bishop, Secretary of the S.P.E.E. is also secretary of the Board. It is interesting to note that three of the members of the Board are members of the A.S.M.E. It is hoped that the Board will later on have funds for a director and staff for the carrying on of the work. One of the policies already adopted is that of securing the active coöperation of the schools themselves in the study of the new problems which are confronting engineering educators. Letters from many engineering schools, now being published in the S.P.E.E. Bulletin, show an active and significant interest in the new movement. The Board also anticipates the coöperation of the various engineering societies and is appreciative of the interest which is being taken by the Mechanical Engineers.

Charles F. Scott.[1]

Engineering Museum Requires Interest and Aid of Entire Profession

The project to establish an engineering museum has attracted wide interest both in the technical and lay press. The matter is now in the hands of a Committee of representatives of the four National Engineering Societies.

Most of the comments on the museum stress its importance as a storehouse for the records of engineering achievement and as an institution affording opportunity for research to the investigator or student. The Secretary of the Smithsonian Institute, in a recent report, concludes that a museum would be a suitable monument showing belated public appreciation of the fact that the commanding place reached by the United States in so short a time is due largely to the full development and utilization of mechanical power in the exploitation of her national resources.

However, a writer in the New York *Tribune* has recently emphasized the high value of such a museum to children in giving them an accurate and inspiring knowledge of mechanical processes. He has a vision of an arrangement of models of the stages of mechanical and industrial developments, a cross-section of the world's mechanical brain, in the various stages of growth, where no boy can spend a day without getting the spark in his soul that may ignite the inventive faculty. This writer's plea is, therefore, for the location of the museum in the midst of the largest number of children, and New York would therefore seem the logical selection. A correspondent has pointed out the industrial greatness of the Middle West and believes that Chicago should be favorably considered. And there are many other diverse ideas on the subject, with the problems multiplying as the interest increases.

The Committee of the Engineering Societies has visited the Smithsonian Institute at Washington and, in coöperation with it, is formulating a plan for a great national museum of engineering and industry similar to the Science Museum at South Kensington, London, the Conservatoire des Arts et Métiers at Paris, and Deutsches Museum at Munich, but suited to the needs of this country. The scheme provides a central institution with branches in different sections and proper exchange facilities.

Ideas regarding the character, scope, and location of the museum and the branches are earnestly solicited by the Committee. Engi-

[1] President, Society for Promotion of Engineering Education.

neers are also urged to preserve the models and records of their original work for eventual deposit in the museum.

Holbrook F. J. Porter is Chairman of the Committee, with offices at the Engineering Societies Building, 29 West 39th Street, New York, N. Y. The representatives of the National Engineering Societies are Edward D. Adams and Charles L. Clarke, representing the American Institute of Electrical Engineers, Frederick A. Delano and Dr. George F. Kunz, representing the American Institute of Mining and Metallurgical Engineers; Clemens Herschel and Nelson P. Lewis, representing the American Society of Civil Engineers; and Reginald P. Bolton and H. F. J. Porter, representing The American Society of Mechanical Engineers.

International Courtesies

The recent announcement of the appointment of Gano Dunn as Local Honorary Secretary in America of the Institution of Electrical Engineers of Great Britain directs attention to a particularly gracious form of courtesy that has just been shown to the United States by the British. Another example of this is the hospitality extended by the national engineering societies of America to the American Section of the Société des Ingénieurs Civils de France. The privilege of the Library and offices are extended to the American Section. This is reciprocated by similar welcome to members of the engineering societies of the United States who live in Paris.

Such incidents emphasize again the great common interests of all members of the engineering profession which can be broadened by still further coöperative effort especially in research and standardization. The engineer as a professional man is rapidly coming into his own sphere of importance in the maintenance and development of civilization and these international contacts will be of great assistance in maintaining a uniform front in engineering activity.

International Engineering Congress, 1926

On Tuesday, January 9, in the Engineering Societies Building in New York, a conference of engineers most experienced in matters relating to engineering congresses was held to discuss the plan, scope, and method of financing of a proposed International Engineering Congress to be held in Philadelphia in 1926 in connection with the Sesquicentennial of the Declaration of Independence of the United States. The movement for this proposed Congress was initiated by the Engineers' Club of Philadelphia, which invited the leading engineering societies to join with it on a committee to formulate a plan.

The secretaries of the engineering societies proposed a plan of organization for an International Engineering Congress which was subsequently approved by those societies and adopted at a meeting of the temporary organization committee held in Philadelphia last summer. Under this plan, a board of management was appointed to organize and conduct a congress under the sponsorship of the engineering societies, and the board appointed, among other committees, a committee on plan and scope. This committee was the body which conducted the public hearing being announced here.

The hearing was virtually an exchange of experiences between those competent to speak on the subject, and among those who addressed the meeting were Messrs. A. M. Hunt, H. Foster Bain, Henry A. Lardner, Fred Lavis, A. R. Ledoux, John W. Lieb, Elmer A. Sperry, M. E. Cooley, Charles F. Rand and F. M. Feiker.

The subjects discussed were scope of the Congress, finances, relation to meetings of engineering societies, relations with governmental agencies, and publicity.

Patent Office Salaries and the Public Interest

The individual members of the Engineering Societies by giving their powerful aid in securing the enactment on February 18, 1922, of the Lampert Patent Office Bill, H.R. 7077, helped to stop the disintegration of the Patent Office by constant resignations and prevented its complete collapse. Without this help it would soon have been swamped and ceased to function usefully.

The Lampert Bill raised the salaries of the Patent Office examiners to $3900 per year and stopped the resignations in the upper grades, where it was most important to stop them. However, the increase from $2750 to $3900 was by far the largest proportionate increase that had ever been obtained through any bill in Congress, and was all that it was possible to obtain at one time. The increased salary is not sufficient, however, to attract men who are highly qualified for the work and to induce them to make a life career of the position, as they must do in order to reach their highest efficiency—in such numbers as to supply all or nearly all of the examining divisions.

The work of an examiner is of great importance to the public interest. By having examiners with sufficient scientific and judicial qualifications and sound judgment and adequate personality, patents will be granted wherever the inventions warrant it, and not be refused because the distinctions of the prior art, although important, are not easily discerned. Such examiners will also with sound judgment detect those cases where the distinctions between the alleged invention and the prior art are not really practical commercial distinctions, but are mere paper differences, and will thereby prevent the granting of patents which can but result in useless litigation that is expensive not only to the patentee and his backers but to the innocent defendant and the Government in the waste of time of the courts.

The inventions which examiners must pass upon are often of great immediate value, and their ultimate value, through their permanent addition to the public domain, are beyond calculation. Therefore, the administration of the Patent Office under examiners of the high type mentioned will increase the market value of patents and thereby stimulate the production of inventions in general—to the great and permanent benefit of the American public.

It is believed that a salary of $5000 for a primary examiner would attract sufficient men of the type described to fill that position in practically all of the examining divisions. There is an excellent opportunity to obtain that salary for the position by aiding in bringing about the enactment of the Sterling-Lehlbach Bill for the Reclassification of Governmental Positions and Salaries, H.R. 8928. This bill has passed the House by a large majority, but in doing so the salary for the position of primary examiner was reduced from $5040 to $4600. The Civil Service Committee of the Senate has reported the bill recommending a restoration to $5040. As the bill affects appropriations, it was also referred to the Appropriations Committee of the Senate, and has been kept there nearly a year by the desire of Senator Reed Smoot to substitute another bill which, while having a different scheme of classification, has substantially the same schedule of salaries.

As the Sterling-Lehlbach Bill has already passed the House, it would obviously be much easier to enact than a substitute bill. The information is that if sufficient public interest is shown, a compromise not affecting the salaries could probably be brought about and the Sterling-Lehlbach Bill reported to the Senate; and if that is done the Bill can be passed through the Senate without great difficulty, after which it seems likely that the House can be induced to agree to the larger salaries.

The Bill has been approved by the following organizations:

The New York Patent Law Association
The National Federation of Federal Employees
The American Federation of Labor
The Federated American Engineering Societies
The American Association of Engineers
The National Civil Service Reform League, and others.

The engineers, chemists, scientists and manufacturers proved with the Lampert Bill that they could induce Congress to pass a just and wise measure in the face of intense opposition. There is no such opposition to the present bill as there was to that bill. Each member of each of the Engineering Societies is asked to write to Senator Smoot and to one of his own senators urging the immediate enactment of the Sterling-Lehlbach Reclassification of Salaries Bill, H.R.8928. If every member will do his duty, it seems more than probable that the bill can be passed and the Patent Office placed on that high plane which its great usefulness warrants.

The enactment of this bill would raise the standard of all professional service under the Government as well as that of Patent Office examiners. Let us all pull together and finish the work which we have so successfully begun.

Edwin J. Prindle.[1]

[1] Chairman, Patents Committee, American Engineering Council.

Dr. Millikan Awarded Edison Medal

THE Edison Medal for 1922 has been awarded to Dr. Robert A. Millikan, of Pasadena, Cal., for "his experimental work in electrical science." The experiments for which he is best known are those dealing with the isolation of the electron.

After receiving the degrees of A.B. and A.M. from Oberlin College Dr. Millikan began teaching physics at the University of Chicago, becoming professor of physics in 1910 and remaining in that capacity until 1921. Since that time he has been director of the Norman Bridge Laboratory of Physics and chairman of the administrative council of the California Institute of Technology. He was granted a Ph.D. from Columbia in 1895 and holds degrees from several other universities in this country and Germany.

Dr. Millikan has written a number of books on physics, besides contributing to the technical press on this subject. He has rendered valuable service as vice-chairman of the National Research Council since 1917 and was a member of the board of editors of the *Physical Review* from 1911 to 1914. In 1913 he was awarded the Comstock prize for research in electricity. Recently Dr. Millikan has been conducting experiments to bridge the gap between light and X-ray phenomena.

Among other recipients of the Edison Medal have been Elihu Thomson, George Westinghouse, Alexander Graham Bell, Benjamin G. Lamme, W. L. R. Emmet, Michael I. Pupin, and C. C. Chesney.

I.E.E. Appoints Gano Dunn Honorary Secretary for United States

THE COUNCIL of the Institution of Electrical Engineers, of Great Britain, has appointed Gano Dunn, president of the J. G. White Engineering Corporation, New York City, honorary secretary of the Institution for the United States, to succeed the late G. G. Ward.

Mr. Dunn is an eminent figure in engineering and will be able to render the Institution valuable service as its local secretary. His association with the J. G. White Engineering Corporation dates from 1913, and for two years previous to that he was vice-president in charge of engineering of the J. G. White & Co., Inc. He was born and educated in New York City, receiving the degree of B.S. and M.S. from the College of the City of New York, and E.E. and honorary M.S. from Columbia.

As a member of numerous technical societies and organizations Mr. Dunn has a wide acquaintance among the engineers of this country. He has served as an officer at two international electrical congresses, the one at St. Louis in 1904 and that at Turin in 1911. He was a delegate to the Second Pan-American Scientific Congress in Washington, 1915, and has served on the Nitrate Commission of the War Department and on the Engineering Committee of the Council for National Defense. He has been a member of the International Electrotechnical Commission, vice-chairman of the National Research Council, chairman of Engineering Foundation, and president of the A.I.E.E., the U.E.S., and the John Fritz Medal Board of Award. He belongs also to the National Academy of Sciences, the Association of Iron and Steel Electrical Engineers, the American Society of Civil Engineers, The American Society of Mechanical Engineers, and The Franklin Institute, as well as to many other technical and fraternal organizations.

New Honors for Colonel Dwight and Mr. Rand

"AN EVIDENT manifestation of the good feeling which exists between the technical men of South Africa and those of the United States" is the light in which the American Institute of Mining and Metallurgical Engineers, in its journal, *Mining and Metallurgy*, views the election of its president, Col. Arthur S. Dwight, to honorary membership in the Chemical, Metallurgical and Mining Society of South Africa. In the conferring of honorary membership upon Charles F. Rand, chairman of the Engineering Foundation, by the Association of Members of American National Engineering Societies in Cuba, a similar internationality of engineers is seen. Both of these engineers have been previously honored by foreign countries, France bestowing upon each the Cross of the Legion of Honor for distinguished service to France and to civilization, and King Alfonso decorating Mr. Rand for his achievements in the development of Cuban iron mines.

Dr. Rosenhain to Lecture in Eastern States

DURING February and March Dr. Walter Rosenhain, head of the metallurgical department of the National Physical Laboratory at Teddington, England, will tour the eastern states, lecturing before various universities and technical organizations on metallurgical subjects. Dr. Rosenhain comes to this country under the auspices of the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers, and will deliver the second annual Institute of Metals lecture, on Solid Solutions, before that body on February 19. Subjects of other lectures will be Hardness and Hardening, The Structure and Constitution of Alloys—to be delivered before Franklin Institute on February 15—Strain and Fracture in Metals, Aluminum Alloys, and Metallurgical Research at the National Physical Laboratory. His itinerary will include Lehigh, Columbia, and Yale Universities, Production Club (Waterbury, Conn.), Massachusetts Institute of Technology, Case School of Applied Science, American Society for Steel Treating (Detroit), University of Illinois, and Engineers' Club of Dayton.

The Charles A. Coffin Foundation

THE General Electric Company, as an expression of appreciation of the constructive service which its founder, Charles A. Coffin, has rendered the electrical industry, has established a fund of $400,000, the income from which is to be used to encourage and reward similar services.

Mr. Coffin, who has been identified with the development of the electrical industry since 1882, founded the General Electric Company and was its leader for thirty years. He retired from active business in May, 1922. The Charles A. Coffin Foundation, created at that time by the Board of Directors of the General Electric Company, is under the direction of a Foundation Committee appointed by the board. The income from the fund recently set aside by the company will be distributed annually in four ways, as follows:

1 Eleven thousand dollars in prizes for the most signal contributions by employees of the General Electric Company toward the increase of its efficiency or progress in the electrical art

2 A gold medal to the public-utility operating company within the United States which, during the year, makes the greatest contribution toward increasing the advantages of the use of electric light and power for the convenience and well-being of the public and the benefit of the industry. The company receiving the medal will also receive one thousand dollars for its employees' benefit or similar fund

3 A gold medal to the electric railway company within the United States which during the year, makes the greatest contribution toward increasing the advantages of electric transportation for the convenience and well-being of the public and the benefit of the industry. The company receiving the medal will also receive one thousand dollars for its employees' benefit or similar fund

4 Five thousand dollars to graduates of American colleges and technical schools who, by the character of their work, and on the recommendation of the faculty of the institution where they have studied, could with advantage continue their research work either here or abroad; or some portion or all of the fund may be used to further research work at any of the colleges or technical schools in the United States. The fields in which these fellowships and funds for research work are to be awarded are electricity, physics, and physical chemistry.

The progress report of the United States Coal Commission which was issued January 15, is the first tangible result of this experiment in basing important economic legislation upon careful investigation. John Hays Hammond, chairman, and George Otis Smith are the engineers on the Commission. E. E. Hunt, a member of the F.A.E.S. Committee on Elimination of Waste is Secretary to the Commission.

Art and the Engineer

VISITORS to the Engineering College of the University of Cincinnati are struck with the artistic atmosphere of the buildings. In place of the starkly framed photographs of machines and locomotives which usually add to the scholastic and technical atmosphere of an engineering school, they find there paintings in oils and water colors of a remarkably high order. Glances at the title plates on the pictures disclose the fact that the paintings in most cases have been presented to the University by the students themselves.

This interest in art at the Engineering College of the University of Cincinnati is of long standing. It has been fostered by Dean Schneider, who believes that the engineering student should be stimulated in art, music, and literature, not only because of the enjoyment and relaxation which an appreciation of art affords, but also because a student well grounded in cultural subjects makes a better engineer. It is possible to introduce him to the liberalizing influences of history and literature through the regular college courses, but a sustained interest in art can be secured only by furnishing him with actual and more or less constant contact with the artistic.

The transformation of the corridors into an art gallery was started in 1916 with the mural decoration of the Library. Upon graduation each class gives a fund varying from six hundred to twelve hundred dollars, while various groups, such as student branches of the national engineering societies, have donated smaller amounts. These gifts have been entirely voluntary and have resulted in a collection of more than fifty paintings, only six of which have not been given by the students.

To maintain the excellence of the collection, the standard for permanent hanging in the Cincinnati Art Museum has been adopted for pictures in the College of Engineering. The Director and Curator of the Museum are consulted in the purchase of pictures. This high standard, and the fact that the pictures become the property of the city of Cincinnati to be hung in perpetuity in a fireproof building of the University, have secured the coöperation of the artists, with resultant benefit to the collection.

The collection is worth study by any engineer who is within reach of it, whether he be an art connoisseur or not. The interest it arouses among students, apparent continually as one passes through the corridors, is ample proof that it must be effective in the lives and works of the engineers who graduate from the University. The competitive system of industry in America has left little time for technical men to study and appreciate the real economic value of culture. So rapid has been our industrial growth that the ideal and artistic aspects of industry have sometimes been forgotten.

Engineers, however, have recognized for some time that wall paper and bridges should be beautiful as well as utilitarian—that machinery should always be the servant of man and, wherever possible, the servant of art. The Engineering College of the University of Cincinnati is graduating men who have learned beauty of line and color through actual contact with it, and who carry with them into the business and industrial world an appreciation of art which is entirely in keeping with the dignity of the profession they have entered.

To fill properly his place, the engineer of tomorrow should be well-rounded in painting and architecture, the arts intimately associated with the guiding ideals of permanence and beauty.

The Illustrations on This Page are Representative of the Collection of Paintings at the Engineering College of the University of Cincinnati

Mortimer E. Cooley
President

P. N. Moore
Vice-President

Calvert Townly
Vice-President

H. E. Howe
Treasurer

Newly Elected Officers of American Engineering Council, Governing Body of the F.A.E.S.

Caetani Welcomed by Engineering Council

Italian Ambassador States Need for Engineering Logic in Public Affairs. Enthusiasm and Action Mark Second Annual Meeting of F.A.E.S. Dean Cooley Re-elected President. Constitution to Be Revised. Notable Resolution Adopted Stating Need for Broader Engineering Training

INTENSITY of purpose and enthusiasm marked the Second Annual Meeting of the American Engineering Council, the governing body of the Federated American Engineering Societies, which was held in the Cosmos Club, Washington, D. C., for two days, January 11 and 12, 1923. The climax occurred during the dinner on the opening evening of the session, at which the guest of honor and principle speaker was the Ambassador from Italy to the United States, Prince Gelasio Caetani, an American engineering graduate and for thirteen years engaged in engineering work in this country. Following the meeting of the Council, the executive Board met to organize the work for the current year.

The Dinner

Dean M. E. Cooley, re-elected President of the Council during the proceedings of the day, presided over the dinner at the Chevy Chase Club. The first speaker of the evening was the Honorable John James Tigert, United States Commissioner of Education. Mr. Tigert is an able orator and his address was a graphic picture of the popular conception of the engineer. He was followed by Secretary Calvin W. Rice, of the American Society of Mechanical Engineers who gave a résumé of his visit to South America where he represented a number of engineering and civic bodies at the International Engineering Congress and the Centennial Celebration of Brazil at Rio de Janerio. Afterwards he visited a number of South American countries and returned with the firm conviction that there is a remarkable opportunity for engineering coöperation with South America. Mr. Rice's inspiring report appeared in the January issue of Mechanical Engineering.

The third speaker was Dr. Elmer A. Sperry who has just returned from a trip to Japan where he presented letters of congratulation from American engineering societies to the semi-jubilee celebrations of two Japanese engineering bodies. He in turn emphasized the necessity for developing the most intimate relations with Japanese engineering organizations.

The messages of international coöperation between engineers and the sentiment expressed by Mr. Rice in his talk that an engineer visiting a foreign country is the most potent ambassador of peace and goodwill was clearly in the minds of those present when Prince Gelasio Caetani rose to begin his address. His fellow engineers gave him a sincere and warm welcome to the country where he had spent the best year of his life, leaving it only at the call of duty to perform feats of wisdom and valor for his own country in the last war. He returns as the representative of the Mussolini government and those who were privileged to meet him and hear him were convinced that his stay will be fruitful to both Italy and the United States. His personal charm and his sincerity held his audience and at the close of his speech he was given an enthusiastic ovation.

Address of Prince Gelasio Caetani

Your kind invitation to be a guest at the annual banquet of the Federation of American Engineering Societies reached me while I was preparing to leave for the United States. I read it with deep satisfaction for it made me feel that, besides sailing for America as Italy's Ambassador, I was going home to my old stamping grounds somewhat still invested with the qualifications of an engineer.

We pride ourselves in saying: "Once an engineer, always an engineer." Whatever may be the course of life followed by any of us, it will always be marked by the indelible seal of the scientific, practical and logical training to which an engineer is subjected during the early years of life.

Some have made the remark in criticism that engineers lack political intuition and ability; I would answer that a larger dose of logic and positiveness applied to politics would bring great advantages to public affairs.

Between Italy and the United States there has never existed political rivalry or serious commercial competition; our relations have been confined almost exclusively to contacts of labor, of engineering, of commerce, of science and of art. Much can be accomplished to the mutual advantage of our peoples; a large share of the success will depend upon the coöperation of the engineers and I know that I will always be able to rely on your goodwill.

I do not hesitate to state that Italy and the United States are at present the most youthful nations of the world. Italy is the oldest one in history and three times has ruled the world; once politically, once spiritually and once intellectually. However, as a political and social unit Italy did not exist from the fall of the Roman Empire to the middle of last century; as race and as nation it had an enforced rest of some fourteen centuries. With the forming of its national unity in 1870 it awakened to a new life; born again as a new being to play its role in world's history, it is healthy, fertile and exuberant of youthful energies. The best proof of this is given by the latest events which led to the establishment of a new national government. The younger and healthiest part of the people, the bulk of the nation, openly rebelled against the old ways which were leading Italy into a critical condition; not only bolshevism and anarchy have been wiped off the map, but also demagogy and all low grade politics aiming to the fostering of party and class interests. In an amazingly short time a complete change of all orders of things was effected, not a miraculous revolution, as some people have thought to style it, because the events were nothing more than a sudden realization of what had been the deep desire and the will of the people to which circumstances so far had not allowed expression. An event that within 24 hours raises the quotations of government securities and restores peace and general confidence, without a drop

of blood being shed or a windowpane broken, cannot be styled a revolution.

The other youngest nation in the world, I was saying, is the United States, the new great power of the history to come; unlimited in its financial powers, unrivaled in its capacity of organization and technical knowledge, wonderful in the possibilities of its vast empire. The coöperation of these two young countries will lead to remarkable results; both our people are laborious and have an inventive, engineering turn of mind.

Italy's largest asset is the remarkable quality of its people's labor; sober, intelligent, hardworking and plastic the Italian peasant or workman will in an incredible short time become efficient in whatever he is called to do.

Of all this many Americans are perhaps not yet fully aware for the reason that the wave of Italian emigration which shortly preceded the war was so sudden that it was not utilized to best advantage.

Much however is still to be done in Italy itself; its resources are far from being fully developed and there are many opportunities for American capital, machinery and technical organization to be usefully applied in Italy.

The electric industry in our country has made rapid strides and as to percentage of utilized water power, Italy ranks, I believe, foremost in the world. Its use results in an economy of about two billion lire, otherwise necessarily spent on fuel imports.

In 1898 the electric energy developed in Italy amounted only to 87,000 kw.; it increased to 426,000 kw. in 1908, to 1,240,000 kw. in 1918 and power plants for some other 1,000,000 kw. are planned or under construction. About 800,000 kw. are still to be developed. On the Tirso in Sardegna a reservoir of 416 million cubic meters capacity is being constructed. It will be the second largest in the world, ranging immediately after the Assuan dam and will develop some 50 million kw-hrs., and irrigate 60,000 acres of land. In the Trentino a reservoir is to be constructed on the Noce torrent of 180 million cubic meters capacity. The dam, 400 feet high, will be practically a concrete wedge driven in a mountain gully, measuring less than sixty feet wide at the base and only 100 feet wide at 300 feet above the bottom. In Southern Italy the large reservoir in construction on the Sila mountain will develop over 110,000 kw. and irrigate large tracks of fertile land. Another interesting plan which is gradually being carried through is to connect the northern power plants, fed by the summer streams of the Alps, with those of central Italy where water is plentiful in winter and rather poor in summer, by a network of high tension lines and by standardization of voltage to obtain a better seasonal compensation than could be secured by the use of even very large reservoirs.

Railroads are to be electrified and telegraphs and telephones are to be reorganized then gradually handed over to private enterprises; experience has proved that state administration of industrial concerns ends always in a financial and technical failure.

I should mention also the large works for reclaiming waste or marshy land by irrigation or drainage. There are 148 enterprises of this kind in Italy for the reclamation of some three million acres of land; of these 35 have been completed covering an area of about 820,000 acres.

My experience in the United States has been my most valuable asset in life. Before leaving Rome, at a dinner given to me by the Italian engineers, I exhorted the young engineers to get a few years of practical training in America. I hope you will do likewise by encouraging your students and graduates to spend some time in Italy as nothing broadens the mind more than to breathe an atmosphere different from that of one's own town and country. Italy's atmosphere is vibrating with wonderful reflexes of a long and glorious past and full of promise for a remarkable future. It is a great art in life to single out and appreciate other people's good qualities and try to make them your own. Similar intercourse between our young students who, in a few years, will be the active men of our countries, will be a powerful factor in reaching the principal and ultimate aim I will have in view in carrying out my duty as Ambassador, that is to strengthen the bonds of friendship and esteem between Italy and the United States.

The Business Session

The opening event at the first business session on January 11 was the presentation of a report by President Cooley, who told of his visits to many local engineering societies during the year. He called for the support of each member of the Council in interesting and inspiring the engineers of the country in the tremendous problems that are facing present day civilization.

Secretary Wallace then related the progress that had been achieved in the work of the Council during the past year. In addition to the routine matters handled by the executive office, Mr. Wallace told of the international interest expressed in the report on Waste in Industry and the Twelve-Hour Shift in Industry. He stated that the Council was firmly established in the mind of official Washington as the representative of a profession that was striving to give disinterested service for the common good. He related the efforts in presenting the facts about a national hydraulic laboratory for the study of river flow and the successful outcome of the struggle on the floor of the House of Representatives for an increased appropriation for topographic mapping. He pointed out however, that while the general information among engineers about the Council and its work was very much better during 1922 than in preceding years, still there was a very severe problem of conveying to every engineer in the United States the importance, the significance and the potentiality of the Federated American Engineering Societies and the American Engineering Council, its governing body.

The report of the treasurer, W. W. Varney, showed a balance of about five hundred dollars for the fiscal year of 1922. Later in the day a budget for the year 1923 of $45,000 was approved. The representatives of the local societies signified their willingness to pay the full assessment of one dollar per member instead of accepting a reduction voted.

Election of Officers

Under the interpretation of the Constitution that the ineligibility of a president for re-election does not apply when the present incumbent is filling out an unexpired term, Dean Mortimer E. Cooley was re-elected as president of the American Engineering Council for a term of two years. Dean Cooley is a member of the delegation of The American Society of Mechanical Engineers. Calvert Townley of the American Institute of Electrical Engineers Philip N. Moore, of the American Institute of Mining and Metallurgical Engineers and Gardner S. Williams of the Detroit Engineering Society were elected as vice-presidents. Mr. Williams was chosen to fill the unexpired term of Dean Dexter S. Kimball of one year and the others will serve the term of two years. Dr. Harrison E. Howe, of the American Institute of Chemical Engineers was elected Treasurer.

Publications

Several times during the meeting the question of the scope and character of a publication for the Council was taken up and discussed. The representatives of the local engineering societies were convinced that a publication was vitally essential and seemed in agreement that it be frequent and of small size. Many expressed the opinion that a publication was the answer to the problem of getting and holding the interest of the individual member of the constituent bodies. The matter was thoroughly discussed and was left to the executive board for the determination of a policy. The present monthly bulletin is to be continued and a resolution was passed which will make it possible to secure second-class mailing rates. The Council also favored the suggestion that a joint news publication of the national engineering societies and the F.A.E.S. be established.

Revision of Constitution

The Council acted favorably on the recommendation of the Executive Board that a committee be appointed to revise the constitution of the Federated Engineering Societies. In the discussion of this motion it was apparent that the members of the Council were in agreement that this be no mere editing but a thorough revision based on a study of the fundamental principles that have been established during the two years of the Council's operation. One action of the Council which may have some effect on the revision of the governing laws was the passage of a resolution that advice and assistance be solicited from each constituent body in so far as this can be done without delaying action.

Two revisions of the by-laws amounting only to interpretations were passed and one change relating to allied technical organizations in foreign countries was laid on the table. It was also decided to provide by constitutional amendment for alternates both for members of Council and for the Executive Board. The consensus of sentiment favored the practice of alternates to the Executive Board being members of the Council.

Government Activities

Several very important actions of the Council related to activities of the Government.

The Council passed the resolution proposed by a committee of the Council at the request of the Boston Society of Civil Engineers recommending that the administration of the Federal Water Power Act be rendered more effective by the maintenance of a permanent, adequate, trained personnel solely for this purpose.

A second resolution recommended that the Bureau of Foreign and Domestic Commerce be authorized to collect and disseminate facts relating to the operation of business.

Compensation and classification of government employees, especially engineers and patent examiners, was given long and careful consideration. The Patents Committee pointed out the need for high grade examiners in the Patent Office which the present government regulations will not permit. The importance of uniform rates of pay for similar kinds of work in different departments was also emphasized. Accordingly, the Council passed a resolution recommending to Congress that adequate rates be provided for the technical employees of the government.

Reforestation

The Committee on Reforestation reported a program by which the entire engineering profession and the public will be educated as to the need for immediate action in reforestation. The perpetuation of the timber supply of the country is a problem that vitally affects, not only the industries that use lumber but also the water supply and the water-power of the future.

Industrial Ideals and Education

Perhaps the most important pronouncement of the Council during the recent meeting was the resolution proposed by the Committee on Industrial Ideals. This resolution relates primarily to the increased present day responsibility of the engineering educator. Many times in discussion of other topics, this responsibility was emphasized and after the passage of this resolution, Professor C. F. Scott, a delegate of the American Institute of Electrical Engineers and President of the Society for the Promotion of Engineering Education told of the remarkable plan developed by the last named society for the preparation of a statement of the fundamentals of engineering education, vital if the engineer is to undertake his great responsibility in the maintenance and development of civilization.

The resolution follows:

Resolved That: The American Engineering Council by action at its meeting on January 11, 1923, desires, on behalf of the Federated American Engineering Societies, to bring to the attention of the engineering colleges throughout the country the need of pointing engineers toward leadership in public affairs.

For a century engineers have directed their energy toward the utilization of the physical forces and the materials of nature. The developments which they have brought about have created an epoch in human history. While these developments have been of inestimable benefit, and modern society could not exist without them, they have introduced many public problems and social readjustments, so closely related to the engineer's activities, that it is increasingly evident he must assume an active part in their solution.

Recognizing this growing need, the engineers of the country formed the Federated American Engineering Societies, primarily to place their knowledge and training at the public service on all public matters affecting engineering, or affected by it.

Engineering education, reflecting closely the attitude of engineers heretofore, has confined its work almost exclusively to scientific and technical training, giving little, if any attention to the social and human aspects of engineering enterprises The American Engineering Council therefore, speaking for the engineering profession, urges upon engineering colleges an increased attention to the social aspects of engineering activities, and a broadening of their technical training, in every way possible, to develop in engineering students the spirit of, and a capacity for, active leadership not only in industry, but in public affairs.

Wellman Memorial Meeting

A notable meeting in honor of Samuel T. Wellman, Past-President A.S.M.E., was held in Cleveland, Ohio on Tuesday Evening January 9th, by the members of the local sections of national engineering societies coöperating with the Cleveland Engineering Society in a series of meetings on the "Iron and Steel Indystry," which are being given by the Associated Technical Societies of Cleveland. The Sections coöperating were:

The American Association for Steel Treating,
The American Chemical Society,
The American Society of Mechanical Engineers,
The American Institute of Mining and Metallurgical Engineers,
The American Association of Iron and Steel Electrical Engineers.

The attendance was large and among those present were many of the prominent engineers of Cleveland and the vicinity, especially the older men who had known Mr. Wellman and his achievements from personal observation over a period of many years that they had together struggled in not only the development of the steel industry but also of the many devices originated in Cleveland, which have contributed so much to the success of the iron and steel industry in America. Mr. Wellman was Past President and also an Honorary Member of the Cleveland Engineering Society.

The meeting was presided over by Mr. F. L. Sessions, Chairman of the Cleveland Section of the American Society of Mechanical Engineers.

The first speaker was Mr. James H. Stratton, a former associate of Mr. Wellman and Engineer of Construction at the Wellman-Seaver-Morgan Co., Cleveland, Ohio. Mr. Stratton in his very fitting remarks regarding Mr. Wellman, stated that one of the best records we have of his achievements were written by Mr. Wellman himself for use in his presidential address[1] before the Annual Meeting of the American Society of Mechanical Engineers in December, 1901.

The first speaker was Ambrose Swasey who had been a life-long friend of Mr. Wellman. Mr. Swasey related many incidents that occurred in their extended travels together which displayed the remarkable qualities of the man. In closing, Mr. Swasey said:

"Mr. Wellman built along broad lines, with noble purposes. He gathered himself friends who were the captains of the steel industry, such as Alexander Holley, Captain Jones of Pittsburgh, and John Fritz. It was Mr. Wellman who called a number of prominent engineers and manufacturers together to give consideration to the celebration of Mr. Fritz's eightieth birthday. The outcome of that conference was a dinner held in the fall of 1902 to celebrate that birthday and at that dinner, the John Fritz medal was established, the greatest honor in the hands of the engineers of America."

The splendid, exceptional steel which Mr. Wellman produced, the wonderful mechanisms which he designed and constructed and sent out into the world, contained those same genuine, dependable qualities which Mr. Wellman possessed to such a remarkable degree. And how true are the words of the young poet Longfellow as regards Mr. Wellman's life and work, "We potters make our pots of what we potters are."

Mr. Clifford C. Smith paid a tribute to Mr. Wellman's foresight shown in his work of improving and developing the basic open-hearth process, the open-hearth charging machine, the ingot charger for the blooming mill and the lifting magnet for handling steel. He also testified to Mr. Wellman's knowledge of paintings, pottery and photography and architecture and the manner he stimulated admiration for these finer things in all those with whom he had contact.

The other speakers were John McGeorge, E. Francis, F. Moeller, A. D. Hatfield and W. G. Hildebran all of whom had been closely associated with Mr. Wellman in various capacities. They related many of the intimate incidents of his life that showed his all around greatness.

In later meetings of the year, the Cleveland Sections of the National societies will discuss the technical phases of the iron and steel industry. Each section will have charge of one meeting.

[1] Transactions, A.S.M.E., vol. 23, p. 78.

Standards for Herringbone Gears for General Commercial Use

Proposed by the A.E.S.C. Sectional Committee on the Standardization of Gears

THE May, 1922, issue of MECHANICAL ENGINEERING contained reprints of the first five gear standards prepared by the Sectional Committee on the Standardization of Gears for which the American Gear Manufacturers Association and The American Society of Mechanical Engineers are joint Sponsors. These five standards having been carefully revised as a result of the criticisms and suggestions received are now before the Sponsor Bodies for final approval and submission to the American Engineering Standards Committee as Tentative American Standards.

At the September meeting the Committee put the finishing touches to the sixth of the gear standards to be completed, and it has recently presented to the Sponsor Bodies this proposed standard for Herringbone Gears for General Commercial Use. This standard is printed below in full for the information of the readers of MECHANICAL ENGINEERING and also to enable them to criticise and comment on this proposal to the Sponsor organizations. All communications should be addressed to Mr. C. B. LePage, Assistant Secretary, The American Society of Mechanical Engineers, 29 West 39th Street, New York.

STANDARD TOOTH FORM

1 *Pressure Angle.* The pressure angle in plane of rotation of gear equals 20 deg.

NOTE: The angle of the cutting tool in the normal plane of the gear at the pitch is 18 deg. 31 min.

2 *Addendum* $= \dfrac{0.8}{P}$

NOTE: P = diametral pitch in plane of rotation.

3 *Dedendum* $= \dfrac{1}{P}$

4 *Clearance* $= \dfrac{0.2}{P}$

5 *Whole Depth* $= \dfrac{1.8}{P}$

6 *Helical Angle.* The helical angle of teeth with axis equals twenty-three (23) degrees.

NOTE: The helix angle of a helical gear is the angle between the helix at the pitch diameter and a plane which contains the axis of the gear.

7 *Enlargement for Pinions.* The enlargement for pinions with 17 teeth or less is given in Table 1.

NOTE (*a*): Enlargement for any given pitch is found by dividing the value given for 1 pitch for the number of teeth desired, by the pitch required.

NOTE (*b*): Calculate the outside diameter as usual, then add the amount of enlargement to the pinion and subtract the same amount from the gear. Use only when pinion has 17 teeth or less.

GEAR-BLANK DIMENSIONS

8 *Pitch diameter* $= \dfrac{N}{P}$

NOTE: N = number of teeth.

9 *Outside diameter* $= \dfrac{N + 1.6}{P}$

10 *Active Face.* Minimum width of active face $= \dfrac{1.6}{P}$

NOTE: Total face is the width of the gear including the groove. Active face equals the total face minus the width of the groove.

11 *Groove.* The width and depth of groove in center of blank for gears cut with hobs at right angles to the axis of the gear are given in Table 2. The letters A, B, and C in the table refer to Fig. 1.

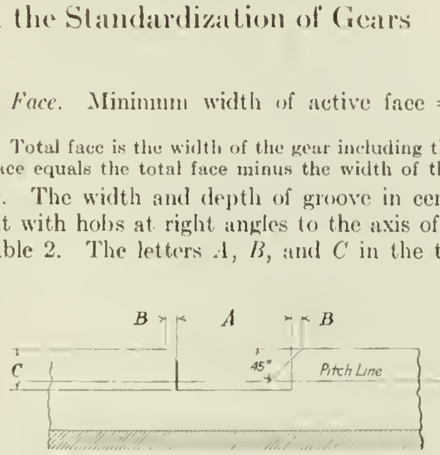

FIG. 1

TABLE 2 DIMENSIONS OF GROOVE

Diametral pitch, inches	A, inches	B, inches	C, inches	No. of threads in hob
10	7/16	1/64	1/8	5
8	7/16	1/64	1/8	4
7	1/2	1/64	1/8	4
6	3/4	1/32	5/32	4
5	3/4	1/32	3/16	4
4	1	3/64	7/32	4
3 1/2	1	3/64	1/4	3
3	1 1/8	1/16	5/16	3
2 1/2	1 3/16	1/16	11/32	3
2	1 5/8	3/32	7/16	3
1 3/4	1 7/8	1/8	1/2	3
1 1/2	2 [illegible]/16	5/32	9/16	3
1 1/4	2 9/16	3/16	11/16	3

TABLE 3 DIMENSIONS OF GROOVE

(Hob set at an angle to axis equal to helix angle minus angle of hob)

Diametral pitch, inches	A, inches	B, inches	C, inches	No. of threads in hob
10	7/8	1/16	5/32	1
8	7/8	1/16	5/32	1
7	7/8	1/16	5/32	1
6	15/16	1/16	5/32	1
5	1 1/8	1/16	3/16	1
4	1 5/16	3/32	7/32	1
3 1/2	1 7/16	3/32	1/4	1
3	1 5/8	1/8	5/16	1
2 3/4	1 13/16	1/8	21/64	1
2 1/2	2	5/32	11/32	1
2 1/4	2 3/16	5/32	3/8	1
2	2 3/8	3/16	7/16	1
1 3/4	2 11/16	3/16	1/2	1
1 1/2	2 7/8	3/16	9/16	1
1 1/4	3 1/8	1/4	11/16	1

TABLE 4 TOOTH-FORM AND SPEED FACTORS

Values of Y				Values of K; $\left(K = \dfrac{3000}{3000+V}\right)$			
No. of teeth	Y	No. of teeth	Y	V	K	V	K
12	0.078	27	0.111	0	1.000	1100	0.731
13	0.083	30	0.114	100	0.968	1200	0.714
14	0.088	34	0.118	200	0.938	1300	0.697
15	0.092	38	0.122	300	0.909	1400	0.681
16	0.094	43	0.126	400	0.882	1500	0.666
17	0.096	50	0.130	500	0.857	1600	0.652
18	0.098	60	0.134	600	0.833	1700	0.638
19	0.100	75	0.138	700	0.811	1800	0.625
20	0.102	100	0.142	800	0.789	1900	0.612
21	0.104	150	0.146	900	0.769	2000	0.600
23	0.106	300	0.150	1000	0.750		
25	0.108	Rack	0.154				

VALUES OF S

Chrome-nickel heat-treated steel, (S.A.E. 3245)	30,000
50 C forged steel (S.A.E. 1045)	25,000
30 C forged steel (S.A.E. 1030)	20,000
Cast steel, A.S.T.M. Class A	15,000
Gray iron	8,000
Bronze, 88–10–2	8,000

TABLE 1 ENLARGEMENT FOR PINIONS

No. of Teeth	Min. No. of Teeth in Melting Gear	Diametral Pitch 10	8	6	5	4	3 1/2	3	2 1/2	2	1 3/4	1 1/2	1 1/4	1
7	28	.1181	.1478	.1976	.2364	.2954	.3382	.3938	.4726	.5906	.6762	.7882	.945	1.181
8	27	.1064	.133	.1782	.2128	.2662	.3046	.3548	.4258	.5322	.6094	.7102	.8514	1.064
9	26	.0947	.1184	.1586	.1894	.2368	.2712	.3158	.379	.4736	.5424	.6322	.7578	.9471
10	25	.083	.1038	.1392	.1662	.2076	.2378	.2768	.3322	.4152	.4756	.5542	.6642	.8302
11	24	.0713	.0892	.1196	.1428	.1784	.2044	.2378	.2854	.3568	.4088	.4762	.5706	.7132
12	23	.0596	.0746	.1002	.1194	.1492	.171	.1988	.2386	.2982	.342	.3982	.4772	.5962
13	22	.0479	.06	.0806	.0958	.12	.1376	.1598	.1918	.2398	.2752	.3202	.3836	.4792
14	21	.0362	.0454	.0612	.0726	.0906	.1042	.1208	.145	.1812	.2082	.2424	.29	.3623
15	20	.0245	.0308	.0416	.0492	.0614	.0708	.0818	.0982	.1228	.1414	.1644	.1964	.2453
16	19	.0128	.0162	.0222	.0258	.0322	.0374	.0428	.0514	.0642	.0746	.0864	.1028	.1283
17	18	.0011	.0016	.0026	.0024	.0028	.004	.0038	.0046	.0058	.0078	.0084	.0092	.0113

12 *Groove.* The width and depth of groove in center of blank for gears cut with *single-threaded* hobs set at proper angle with axis of gear are given in Table 3. The letters A, B, and C refer to Fig. 1.

13 *Groove.* The width and depth of groove in center of blank

(*Continued on page 146*)

Coöperation between Federal Specifications Board and Industry Promoted by A.E.S.C.

AN IMPORTANT step toward the elimination of the differences between specifications for Government purchases and the usual practice of commercial suppliers has been taken through the appointment by the American Engineering Standards Committee of a standing Committee on Coöperation with the Federal Specifications Board. Such differences in practice between Government and commercial orders are often responsible for the statement, common in commercial circles, that it costs 10 per cent more to do business with the Government than with other customers.

The members of the Committee on Coöperation with the Federal Specifications Board are:

A. H. HALL, *Chairman*, assistant treasurer and superintendent of distribution, Central Union Gas Company, New York City.

JOHN A. CAPP, chief of the testing laboratory, General Electric Company, Schenectady, New York.

SULLIVAN W. JONES, chairman, Structural Service Committee, American Institute of Architects, 19 West 44th Street, New York City.

The appointment of this committee is the culmination of conferences between Dr. S. W. Stratton, Chairman of the Federal Specifications Board, other Government officials, and representatives of industry extending over a period of several months. It is expected that in future editions a large part of the specifications will go through the regular procedure of the American Engineering Standards Committee, in order that the industrial and government specifications may be unified, resulting in truly national specifications recognized by industry and Government alike.

It is the unanimous opinion of the Federal officials and the officers of the A.E.S.C. that this coöperation between manufacturing industries, the Government and other consumers produced a widening of the source of supply for all Government requirements and in economies running into many millions of dollars yearly.

The Federal Government is one of the largest purchasers of industrial products, both as to the amount and the range of supplies. The diversity of the various Government specifications, their departures from usual commercial production, and the special features frequently required became very troublesome to the manufacturing industries; this remained true to a large extent until very recently. This Board has adopted nearly 40 specifications and is actively at work on many more.

It is the aim of the Federal Specifications Board to bring into line with the best commercial practice, not only the specifications which are to be approved by the board in the future, but also those which have already been approved. The latter will be accomplished when the approved specifications come up for review and possible revision. Such review is planned at intervals of one year.

System for Numbering Steels to be Developed Under Procedure of A.E.S.C.

A SYSTEM of designating kinds or qualities of steels by code numbers, each of which would represent a definite specification, will be developed as a result of the decision of a conference of the principal producers and users of steel held at Washington, D. C., December 6, at the call of the American Engineering Standards Committee. The conference recommended that this code be developed under the procedure of the A.E.S.C. and suggested to that organization the appointment of the Society of Automotive Engineers and the American Society for Testing Materials as joint sponsors for the code.

The agreement to go ahead with this project was arrived at after a spirited discussion concerning the necessity for and practicability of a numbering system. Strong opinions in favor of the designation of steels by number were voiced by heavy buying interests, such as the U. S. Navy Department, the Electrical Manufacturers' Council, the Society of Naval Architects and Marine Engineers, the U. S. War Department, and the Federal Specifications Board. It was pointed out during this discussion that shipbuilders use every conceivable variety of steel. Opposition to the inclusion of tool steel was voiced by tool-steel makers.

The conference voted that it is desirable to have a uniform numbering system, based on specifications, for forging steels, casting steels, structural steels including plates, tool steels, and other steels, this decision, with the exception of tool steels, being taken without dissent. Whether the basis for such a numbering system should be chemical composition, physical properties, or heat treatment was left to be determined by a Sectional Committee the personnel of which is to be approved by the American Engineering Standards Committee. It was also left to the Sectional Committee to decide whether there are any existing systems which can be used as a basis for numbering codes for any or all of the various groups of steels. The question of whether brand names can be accommodated to and associated with a numbering system was brought up, but the consensus of opinion was that this is not practicable.

The conference was opened by a résumé of present American practice in designating steels by Dr. G. K. Burgess, Chief of the Division of Metallurgy of the U. S. Bureau of Standards, and a résumé of European practice by L. H. Fry, representing the American Society for Testing Materials. Mr. Fry said that Switzerland and Germany have already taken definite steps toward a numbering system. The method proposed in Switzerland provides a system of symbols intended to be universal and definite, and capable of expansion to suit new requirements. In France a method is offered by which steels will be numbered with relation to a definite specification for the type, augmented by a letter indicating the method of manufacture, and a number showing the minimum tensile strength. In Great Britain a numbering system is employed for aircraft steels, and a tendency is appearing to develop symbols for automobile steels. Some limited symbolization is used in Holland also. A copy of Mr. Fry's full report, which is based on information obtained from abroad by the A.E.S.C., will be sent upon request to the American Engineering Standards Committee.

Dr. Burgess presided at the conference, which was attended by thirty-two men representing twenty-two organizations.

The recommendations of the conference were presented to the American Engineering Standards Committee, at its meeting on December 14. The Committee took the following action:

Resolved, That the American Society for Testing Materials and the Society of Automotive Engineers be designated joint sponsors for the development of a numbering system for forging, casting, and structural steels, including plates, but not including tool steels, the numbering system to be based on definite specifications, and—

Resolved, That for the present the question of developing such a numbering system for tool steels be held in abeyance.

Standards for Herringbone Gears

(*Continued from page 145*)

for gears cut by planing or shaping methods equal respectively:

Width = $1^1/_8$ in.

$$\text{Depth} = \frac{1.8}{P} + \text{suitable clearance.}$$

14 *Horsepower Rating.* For Pitch-Line Velocities up to 2000 Feet per Minute:

$$\text{Horsepower} = \frac{WV}{33{,}000}$$

where $W = \frac{S}{2} PFYK$

(Formula safe for wear when well oiled. For grease lubrication multiply by factor of from 0.8 to 0.62)

W = load in pounds
S = working stress (no speed) (See Table 4)
P = circular pitch
Y = tooth-form factor from Table 4
F = width of active face in inches. (For continuous contact of teeth, minimum face = 6 P)
K = speed factor from Table 4
V = pitch-line velocity in feet per minute

LIBRARY NOTES AND BOOK REVIEWS

A Dictionary of Applied Physics

Dictionary of Applied Physics, Edited by Sir Richard Glazebrook, in 5 Volumes. Vols. 1 (Mechanics, Engineering, Heat) and 2 (Electricity) Macmillan Co., London, 1922. Cloth, 6 × 9 in., 1067 pp. and 1104 pp., illus. Price $15.00 each.

A fundamental work, the various sections of which have been prepared by men of international reputation in their particular lines.

The mechanical engineer will be particularly interested in the first volume, which covers mechanics, engineering, and heat. As an illustration of the extensiveness of treatment of the various subjects considered, it may be noted that the physics of the steam turbine are treated by Gerald Stoney and Telford Petri in a 20-page article, and that the development of the steam turbine is discussed by Robert Dowson in an additional 18 pages. Other subjects are dealt with on a similar generous scale, both as regards the space devoted to them and thoroughness of handling. Many of the articles represent a successful attempt to bring together in a concise and craftsmanlike form the latest information on recent tendencies in machine design. Such, for example, are the article on the balancing of engines and prime movers (Vol. 1, pp. 252–267), by Wm. Ernest Dalby and the extremely interesting contribution on elastic constants (Vol. 1, pp. 115–241) by Reginald G. Batson.

One cannot help feeling, however, that certain subjects have been treated all too briefly. For example, the eleven pages devoted to the theory of elasticity by R. V. Southwell, notwithstanding their interest, do not present the matter as completely as the importance of the subject warrants.

It would appear generally that the Dictionary of Applied Physics places limits on the space devoted to strictly engineering developments that have been extensively covered by treatises: for example, the whole subject of refrigeration receives only 13 pages, and even the important matter of cryogenation (liquefaction of gases) is handled in eight pages; on the other hand, the subject of the realization of an absolute scale of temperature is given thirty-five pages.

Notwithstanding this apparent (and it is only apparent) inequality of treatment, the two volumes thus far issued represent not only a tremendous amount of work, but what is more, a fairly complete summary of our knowledge of applied physics within the range treated, and as such they are on a par with works such as Thompson and Tait's Natural Philosophy.

Among the subjects to which considerable space is devoted the following may be cited: Ship Resistance, Geo. S. Baker; Kinematics of Machinery, Chas. H. Bulleid; Reciprocating Steam Engine, Andrew Cruickshank; The Water-Cooled Petrol Engine, Aubrey T. Evans; Simple Harmonic Motion, Horace Lamb; Stream-Line Motion, Horace Lamb; Friction, T. E. Stanton; Thermodynamics of Internal-Combustion Engines, Sir Dugald Clerk; Theory of Steam Engine, Sir James A. Ewing; Latent Heat, Ezer Griffiths; Conduction of Heat: Mathematical Theory, Horace Lamb; Thermal Expansion, Alfred Wm. Porter; and Specific Heat of Gases, David R. Pye.

Analysis of Rubber. By John B. Tuttle. Chemical Catalog Co., N. Y., 1922. (American Chemical Society. Monograph Series.) Cloth, 6×9 in., 155 pp., $2.50.

A detailed critical summary of methods for the analysis of rubber and rubber goods, addressed primarily to chemists in consumers' laboratories and to those without previous experience in the technology or analysis of rubber. Includes an extensive bibliography. In addition to analytical methods, the book contains brief accounts of the composition of crude rubber, the preparation of rubber compounds, the theory of vulcanization and methods for physical testing.

Chauffage des Chaudières au Charbon Pulvérisé. By Michel Sohm. Chaleur et Industrie, Paris, 1922. Paper, 9×11 in., 38 pp., illus., diagrams, 4 fr. 25.

The Compagnie des Mines de Bruay has recently installed, in its electric plant at Labuissière, a powdered-coal plant for firing its boilers, which is one of the largest in Europe. This pamphlet, by the engineer in charge, describes the plant in great detail, together with its constituent parts, gives a record of the results obtained in operation and conclusions as to the merits of pulverized coal.

Diesel Engines for Land and Marine Work. By A. P. Chalkley. Fifth edition. D. Van Nostrand, N. Y., 1922. Cloth, 6×9 in., 330 pp., illus., diagrams, tables, $6.

Since the last edition of this work was published in 1915, the Diesel engine has been greatly developed and adopted much more widely. Many new manufacturers have arisen and many new types have been developed. In the present revised edition, these new engines have been dealt with as fully as possible and their salient features described. In addition to descriptive matter, the theory, installation, testing, operation and design of Diesel engines are treated.

Elasticity and Strength of Materials Used in Engineering Construction. Section 1. By C. A. P. Turner. Published by the Author, Minneapolis, Minn., 1922. Cloth, 6×9 in., 85 pp., illus. tables.

This volume is intended to demonstrate the fundamental principles upon which rational analysis may be founded and to discuss the properties of the commonly used materials from the point of view of elasticity. It presents, for the first time, a development of the relations of residual to elastic strain sufficient to account for elastic phenomena not understood heretofore and discusses the error resulting from general misunderstanding of these relations. Here is also demonstrated, for the first time, that there is but one independent modulus of elasticity for the resistance of a homogeneous isotropic solid. The relative value of the coefficients for such a body and their modification by residual strain are investigated.

Engineering Inspection. By E. A. Allcut and Chas. J. King. Van Nostrand Company, N. Y., 1922. Cloth, 7×10 in., 187 pp., illus., diagrams, tables, $5.

Much descriptive matter has already been written on the details of the various inspection methods used in different engineering works, but the object of this work is to present a convenient description of the various principles involved in the inspection of an engineering job from the raw material to the finished job. The examples given are representative ones, illustrating the different principles of inspection and measurement in common use. The book is confined to mechanical-engineering operations.

Engineering Workshop Handbook. By Ernest Pull. Fifth edition. D. Van Nostrand, N. Y., 1922. Cloth, 4×7 in., 175 pp., illus., diagrams, tables, $5.

This little pocketbook is intended for apprentices and machinists. It includes workshop mathematics, the heat treatment of metals, descriptions of the common tools and machines and of the usual operations, lathe work, screw cutting, drilling, planing, milling, grinding, etc. The book will be useful to beginners.

Etude sur le Ballon Captif et les Aéronefs Marins. By Charles Lafon. Gauthier-Villars et Cie, Paris, 1922. Paper, 7×10 in., 206 pp., 20 fr.

Although the elongated captive balloons known as "sausages" have been used by the French navy since 1917, there has not existed, until now, an exact theory of the equilibrium of the balloons watching over moving vessels. The present volume presents important scientific ideas upon towed balloons and naval aerial tactics. It also contains new data and diagrams of interest in the navigation and maneuvers of naval forces.

Flow of Gases in Furnaces. By W. E. Groume-Grjimailo. With an Appendix upon The Design of Open-Hearth Furnaces, by A. D. Williams. John Wiley & Sons, N. Y., 1923. Cloth, 6×9 in., 399 pp., illus., $5.50.

Upon the basis of extended observations in practice and careful experimental researches, Professor Groume-Grjimailo has formulated a hydraulic theory of flow of heated gases, developed the laws governing this flow, and shown how these may be applied in designing furnaces for industrial purposes. Extensive appendices, amounting to over one-half of the text, contain formulas and tables upon gas flow and arch brickwork, together with several articles by Mr. Williams, treating of the design of open-hearth furnaces and hot-blast stoves, combustion and boiler settings, and heat-capacity and calorific-intensity curves.

La Force Motrice Electrique dans L'Industrie. By Eugéne Marec. Gauthier-Villars et Cie., Paris, 1922. Paper, 7×10 in., 613 pp., illus., diagrams, 55 fr.

A practical treatise for engineers interested in the industrial application of electric power. Intended to explain the fundamental characteristics of commercial electric machines, in order to facilitate the choice of proper equipment, and to explain how this equipment should be installed, operated, and maintained. Includes descriptions of accessory machinery and equipment, and shows many examples of the application of motor drive to various classes of machinery.

Les Hélicoptères. By W. Margoulis. Gauthier-Villars et Cie., Paris 1922. Paper, 6×9 in., 90 pp., diagrams, 10 fr

Part one of this volume is based on M. Margoulis's experimental investigation of screw propellers, which has enabled him to trace, for the first time, the characteristic curves of the most general action of a screw propeller. In the second part, the results of experience are applied to the study of the flight of a helicopter, in vertical and oblique flight.

Industrial Applications of X-Rays. By P. H. S. Kempton. Isaac Pitman & Sons, London, 1922. (Pitman's Technical Primers.) Cloth, 4×7 in., 112 pp., illus., 2s. 6d.

A concise account of the apparatus used to produce X-rays and the methods of using them to examine metals, non-metals and composite structures of various kinds. A bibliography is also included.

Introduction to the Calculus. By William F. Osgood. Macmillan Company, New York, 1922. Cloth, 5×8 in., 449 pp., $-.90

A revision of the author's First Course in the Differential and Integral Calculus. The plan of treatment is the same, but the presentation is fuller. The objects of the book are to set forth the application of the calculus to problems of geometry and physics of the first order of importance, and to make clear the thought that underlies the calculus. The book is intended for the engineer, the physicist and the student of pure mathematics.

Lubrication and Lubricants. By J. H. Hyde. Isaac Pitman & Sons, London, 1922. (Pitman's Technical Primers.) Cloth, 4×7 in., 114 pp., illus., diagrams, tables, 7×4 in., cloth, $0.85.

Outlines, in as simple a manner as possible, consistent with the assumption of a general knowledge of engineering terms, the function of lubricants, the types, their application, the nature of friction and the theory of lubrication. Methods of mechanical, physical and chemical testing are described, recent developments in lubrication are discussed and a number of important examples of lubrication and lubricators are given.

Measurement of Gas and Liquids by Orifice Meter. By Henry P. Westcott and John C. Diehl. Second edition. Metric Metal Works, Erie, Pa., 1922. Fabrikoid, 5×8 in , 434 pp., illus., diagrams, tables, $4.50.

Authoritative information on the orifice meter and its uses for measuring air, steam, water and oil. The first section of the book gives general information on the meter. Section two discusses the physical properties of fluids. Section three is devoted to measurement by orifice meter, while the remaining sections describe its application for various purposes.

Mechanical Handling and Storing of Material. By George Frederick Zimmer. Third edition. D. Van Nostrand, N. Y., 1922. Cloth, 8×11 in., 804 pp., illus., diagrams, $15.

An elaborate monograph on methods and machines for handling materials continuously or intermittently, for loading and unloading, and for automatic weighing. The most complete work in English on elevating and conveying machines, cableways, bridge cranes, warehousing machinery, etc. In this edition obsolete installations and devices have been deleted or replaced by modern examples, and the examples of American or Continental practice have been replaced by examples of British manufacture. The text has been carefully revised throughout.

Motor Vehicle Engineering; The Chassis. By Ethelbert Favary. First edition. McGraw-Hill Book Co., New York, 1922. Cloth, 6 × 9 in., 468 pp., illus., diagrams, $5.

In this volume, as in the preceding volume on engines, the author endeavors to present, in simple language and with only elementary mathematics, the information required by the automotive engineer and the designer. It is not intended as a history of automobile development, nor as a mere description of present practice as exemplified in the vehicles now being manufactured, but to explain the theory that underlies the design of the automobile chassis.

Production Engineering and Cost Keeping for Machine Shops. By William R. Basset and Johnson Heywood. First edition. McGraw-Hill Book Co., New York, 1922. Cloth, 6×9 in., 311 pp., illus., $3.50.

Written to bring practical assistance to the production managers, foremen and cost accountants of machine shops, and to give higher executives a knowledge of good shop-management practice, so that they may judge the effectiveness of the methods of their subordinates. Methods are given in detail, and the reasons explained. Language devoid of technicalities is used. The costkeeping methods described are suitable, in the author's opinion, for nine-tenths of all the American machine shops.

Production Grinding. By Fred B. Jacobs. Penton Publishing Co., Cleveland, 1922. Cloth 6 × 9 in., 238 pp., illus., $3.

Describes the methods used in representative plants for cutting and finishing machine parts. Includes the practice of the Marmon, Packard, Oakland, Chevrolet, and Ford automobile plants, methods for finishing chilled-iron valve cams, ball and roller bearing production, grinding operations in the making of dental tools, finishing calender rolls, reconditioning automobile engines, die grinding and the making of milling cutters. Full data are given concerning methods and output.

Railroad Construction. By Walter Loring Webb. Seventh edition, revised and enlarged. John Wiley & Sons, New York, 1922. Fabrikoid, 4 × 7 in., 847 pp., illus., diagrams, tables, $5.

Important changes and additions have been made in relation to the shrinkage of embankments; the laws governing the life of ties; substitutes for wooden ties; rail specifications, testing, failures, wear; rail-joint failures; water-tank construction; hump yards, yard grades; train resistance; and stresses in track.

Reign of Rubber. By William C. Geer. Century Co., New York, 1922. Cloth, 5 × 8 in., 344 pp., illus., map, $3.

An interesting account of the rubber industry, written in popular style and fully illustrated. Describes the development of the industry from its beginnings and explains how certain representative rubber products, such as tires, footwear and clothing, golf balls, electric conductors, hose, belting, packing and balloon fabrics, are made. Intended for users of rubber goods, rather than for makers.

Researches on Cellulose, Vol. 4, 1910–1921. By Charles F. Cross and Charles Dorée. Longmans, Green & Co., New York, 1922. Cloth, 5 × 8 in., 253 pp., diagram, tables, $5.

These volumes of researches, of which this is the fourth, are intended as supplements to the original volume on cellulose, published in 1895. They provide a review and critical evaluation of the research work upon the constitution and properties of cellulose which has been published in various technical journals, together with certain new matter contributed by the reviewers.

Short Handbook of Oil Analysis. By Augustus H. Gill. Tenth edition. Lippincott, Philadelphia, 1922. Cloth, 5×8 in., 223 pp., tables, $2.50.

A concise manual, primarily for beginners, giving the methods of applying the usual physical and chemical tests to mineral, animal, and vegetable oils. Discusses only the more commonly occurring oils, as regards their preparation, properties, analytical constants, uses and adulterants. This edition has been revised and a section on motor gasoline and a description of the MacMichael absolute viscosimeter have been added.

Shield and Compressed-Air Tunneling. By B. H. M. Hewett and S. Johannesson. First edition. McGraw-Hill Book Co., New York, 1922. Cloth, 6 × 9 in., 465 pp., illus., diagrams, tables, $5.

The authors state that so much tunneling has been done with the aid of the shield and the art of such work has been developed to such a point that it is now possible to formulate, to some extent at least, certain principles and rules of practice on which to base the design and construction methods of future work. This they have tried to do in the present book, which treats of tunnel design, stresses in tunnel linings, methods of lining, tunnel shields, plant and equipment, methods of construction, maintenance and inspection, progress, cost, and surveying. A chapter is devoted to compressed-air sickness. A good bibliography is included.

Sparking Plugs. By A. P. Young and H. Warren. Isaac Pitman & Sons, New York, 1922. (Pitman's Technical Primer Series.) Cloth, 4 × 6 in., 106 pp., illus., diagram, tables, $0.85.

This little book reviews briefly the history of spark plugs and discusses the general principles of electric ignition. The operation and design of spark plugs is then considered in detail. The questions of electrodes and voltages are treated in detail, with data from researches by the authors. This is followed by a consideration of the composition and properties of spark-plug insulators.

Steam Turbine; Theory and Practice. By William J. Kearton. Isaac Pitman, New York, 1922. Cloth, 6 × 9 in., 456 pp., illus., diagrams, $4.50.

In the opinion of Mr. Kearton, many recent books on the steam turbine have been over-developed along certain lines, and few have been generally useful to the student. The present work is written for the student, and should prove useful to engineers and draftsmen desiring a wider knowledge of theory.

After introductory chapters on the properties of steam and entropy, the book treats of the steam-turbine cycle, the flow of steam through nozzles and blades, efficiency, lubrication, stresses, critical speed, and turbine design. This is followed by descriptions of commercial turbines of various types.

Steam-Engine Principles and Practice. Terrell Croft, editor. First edition. McGraw-Hill Book Co., N. Y., 1922. Cloth, 6×8 in., 513 pp., illus., diagrams, $3.50.

This book has been very carefully prepared, the author states, to satisfy the demand for a "practical" book containing the information concerning steam engines which is wanted by an operating engineer or plant superintendent. Nothing pertaining to design has been included. The treatment has been directed to the selection, operation, care and repair of steam engines and to questions of economic operation.

A.S.M.E. Boiler Code Committee Work

(*Continued from page 137*)

integral part of the boiler? The thickness for heads which have riveted construction is not definitely specified in this paragraph.

Reply: It is the opinion of the Boiler Code Committee that the term "riveted shells" in the first sentence of this paragraph is intended to cover heads, in case they are not used as tube sheets.

Case No. 409

Inquiry: Is it permissible, under Par. M-11 of the Code for Miniature Boilers, to weld on to the shell a half-coupling for the reinforcement to give the necessary four full threads?

Reply: It is the opinion of the Committee that the reinforcing may be accomplished only by a riveted pad or its equivalent, or by building up the thickness of the plate by welding, and that the welding of the half-coupling on the outside of the plate is not permissible under this requirement.

Case No. 410

Inquiry: Is it the intent of Par. M-16 of the Code for Miniature Boilers that non-ferrous metal shall be used for the valve seat and also that the lifting device shall be of non-ferrous metal, as are required by Pars. 282 and 283 of the Power Boiler Section of the Code?

Reply: Attention is called to the fact that where the Rules of the Code for Miniature Boilers do not apply, those as above referred to in the Power Boiler Section of the Code are applicable.

Some Technical Bibliographies

THE following list of bibliographies on technical subjects has been compiled by Raymond N. Brown, of the Engineering Societies Library, 29 West 39th St., New York, N. Y., where all of the publications named are to be found. The photostatic service as described in The Engineering Index may also be used in connection with this index. Bibliographies upon any technical subjects will be compiled by the Library, upon request, at the rate of two dollars an hour.

Alcohol, Power. Power Alcohol, Its Production and Utilization. H. Frowde, London, 1922, 323 pp. Extensive lists of references are found at the end of each chapter.

Beams, Vierendeel System, Calculation of. Statik der Vierendeeltrager, Karl Kriso. J. Springer, Berlin, 1922, 288 pp.; bibliography, pp. 287–288. About 50 references, mostly to German publications.

Cast Steel. Der Stahlguss als Werkstoff, Rudolf Schafer. Giesserei-Zeitung, vol. 19, pp. 463–472 and 474–482; bibliography, p. 482. Sixty-four references, all in German.

Chrome Refractories. Chrome Refractories, J. S. McDowell and H. S. Robertson. American Ceramic Society, Journal, vol. 5, pp. 865–887; bibliography, pp. 882–887. About 130 references arranged chronologically.

Combustion, Surface. Surface Combustion, R. F. Bacon and W. A. Hamor. American Fuels, 2 vols., McGraw-Hill Co., Inc., New York, 1922. Bibliography in vol. 2, pp. 1091–1094. About 80 references arranged chronologically.

Duralumin. Duralumin: A Digest of Information, H. C. Knerr. American Society for Steel Treating, vol. 3, pp. 13–42; bibliography, pp. 41–42. Twenty-eight references.

Dust Explosions. Dust Explosions: Theory and Nature of Phenomena; Causes and Methods of Prevention. National Fire Protection Association, Boston, 1922, 246 pp.; bibliography, pp. 241–246. About 150 references arranged chronologically.

Graphic Charts. Graphic Charts in Business—How to Make and Use Them, A. C. Haskell and J. G. Breaznell. Codex Book Co., Inc., New York, 1922, 250 pp.; bibliography, pp. 239–246. Over 40 books and about 140 periodical articles are listed. The latter are classified.

Lumber. Lumber, Its Manufacture and Distribution, R. C. Bryant. John Wiley & Sons, Inc., 1922, 539 pp.; bibliography, pp. 439–448. About 180 references arranged by classes.

Metals, Non-Ferrous, Season Cracking of. Bibliography on Season Cracking. British Non-Ferrous Metals Research Association, Bulletin, no. 6, July, 1922, pp. 14–18. Forty-seven references in chronological order.

Partitions, Sound-Proof. Sound-Proof Partitions, F. R. Watson. University of Illinois, Engineering Experiment Station, Urbana, Ill., Bulletin 127, 1922, 85 pp.; bibliography, pp. 77–78. Thirty-four references.

Steel, High-Speed Tool. Bibliography of High-Speed Tool Steels. American Society for Steel Treating, Transactions, vol. 3, pp. 47–89. About 360 references with descriptive notes covering period from 1900 to May, 1922. Divided into parts entitled: I, Manufacture of High-Speed Steel; II, Heat Treatment; Uses and Tests. Arranged chronologically in each part.

Steel, Rustless. Rostfreie Stahle, Karl Daeves. Stahl und Eisen, vol. 42, pp. 1315–1320; bibliography, pp. 1319–1320. Thirty-two references.

THE ENGINEERING INDEX

(Registered United States, Great Britain and Canada)

Exigencies of publication make it necessary to put the main body of The Engineering Index (p. 101-EI of the advertising section) into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.

AERODYNAMICS

Standardization. Standardization and Aerodynamics, William Knight. Aerial Age, vol. 15, no. 21, Dec. 1922, pp. 593–598. Writer refers to suggestions contained in his report to Nat. Advisory Committee for Aeronautics made in 1919 on desirability of calling a congress of representatives of leading aerodynamic laboratories, without discrimination between former allies and enemies and gives comments of the various countries on proposed congress.

AIRSHIPS

Girders. Improvements in Built-Up Airship Girders, S. H. Phillips. Aviation, vol. 13, no. 26, Dec. 25, 1922, pp. 828–830, 3 figs. With special reference to strength of girders as a whole.

AIR COMPRESSORS

Rotary. Rotary Air Compressors. Engineering, vol 114, no. 2972, Dec. 15, 1922, pp. 740–742, 15 figs., partly on p. 744. New compressors constructed by Swiss Locomotive & Machine Works, Winterthur, Switzerland.

AMMONIA CONDENSERS

Comparative Reports. Comparative Ammonia Condenser Reports Point Out Inefficiencies, P. Wilson Evans. Power, vol. 57, no. 1, Jan. 2, 1923, pp. 28–30, 1 fig. By compiling weekly averages of ammonia condenser temperatures and pressures from various plants operated by Armour & Co., it has been possible to detect and remedy inefficient operating conditions with resultant saving in power and operating expense.

BLAST FURNACES

Air Intake, Elevated. Elevated Intake for Blast Furnace Air, Alfred Gradenwitz. Iron Age, vol. 110, no. 26, Dec. 28, 1922, p. 1700, 1 fig. Tests at Rombach Iron Works, Coblentz, Germany, with view to ascertaining whether upper strata of air are cooler and less capable of absorbing water than those in immediate vicinity of ground; 138-ft. suction tower for air intake affords considerable reduction of moisture.

BOILER ROOMS

Efficiency in. Modern Management Methods in the Power Plant, Browning Robinson. Indus. Management (N. Y.), vol. 65, no. 1, Jan. 1923, pp. 57–61, 2 figs. Problems of boiler-room efficiency.

BOILERS

Design. Principles of Boiler Design, C. E. Stromeyer. Engineer, vol. 134, no. 3495, Dec. 22, 1922, pp. 672–673, 1 fig. High-furnace-temperature effects; convection and velocity; costly natural draft; air heaters; superheaters; economizers; high velocity of flames; reductions of furnace temperatures; oil burning.

BONUS SYSTEMS

Packard Motor Co. A New Departmental Bonus System, E. F. Roberts. Indus. Management (N. Y.), vol. 65, no. 1, Jan. 1923, pp. 43–45, 3 figs. Method adopted by Packard Motor Car Co. for stimulating efficiency.

BOXES

Cardboard, Machinery for Making. Cardboard Box-Making Machinery. Engineering, vol. 114, nos. 2965, 2966, 2967, 2968, 2969, 2970, 2971 and 2973, Oct. 27, Nov. 3, 10, 17, 24, Dec. 1, 8 and 22, 1922, pp. 517–520, 542–543, 578–579, 609–610, 640–641, 670–671, 698–699 and 760–762, 103 figs. Complete range of machinery used in manufacture of cardboard boxes.

CENTRAL STATIONS

Pulverized-Coal Burning. Cahokia Station. Power, vol. 57, no. 1, Jan. 2, 1923, pp. 20–22, 4 figs. Outstanding engineering features of new station of Union Elec. Light & Power Co., St. Louis, Mo., as example of large central station using pulverized coal as fuel.

CORROSION

Metals, Industrial. Corrosion as Affecting the Metals Used in the Mechanical Arts, W. H. Hatfield. Engineer, vol. 134, no. 3494, Dec. 15, 1922, pp. 639–643, 21 figs. Results and other data of set of experiments undertaken to decide upon relative resistance to various corroding media of typical industrial metals. Paper read before Sheffield Assn. Metallurgists & Met. Chemists.

COST ACCOUNTING

Factory. A New System of German Factory Accounting, Schar Schlesinger and Wallichs. Management Eng., vol. 4, no. 1, Jan. 1923, pp. 27–31. Describes system of cost accounting developed by Ernst Just and Elizabeth Vöhl, based on principle of applying analytical methods as substitute for experience and intuition. Presents and discusses seven propositions upon which system is based. If generally adopted a radical change will take place in industrial organizations.

Measuring Management by. Measuring Management by Cost Accounting, William R. Basset. Am. Mach., vol. 58, no. 1, Jan. 4, 1923, pp. 37–38. Effect of human factor; lack of unit of measurement; cost-finding methods considered most effective present measure.

DIE CASTINGS

Dies for. Dies for Die-castings, A. G. Carman. Machy. (N. Y.), vol. 29, no. 5, Jan. 1923, pp. 369–370, 3 figs. Specific examples of design and construction of dies for making die castings of more intricate type.

DIES

Shells, Blank Diameters of. Blank Diameters for Drawn Shells, W. L. Tryon. Machy. (N. Y.), vol. 29, no. 5, Jan. 1923, pp. 349–354, 19 figs. Formulas and graphical methods for finding blank area and diameter of various types of shells.

DIESEL ENGINES

Nobel. The Two-Stroke-Cycle Diesel's Superiority for Large Powers, Edwin Lundgren. Power, vol. 56, no. 26, Dec. 26, 1922, pp. 1015–1016, 2 figs. Points of superiority of two-stroke-cycle engine illustrated with data on Nobel-Sweden 1600-hp. Diesel.

ELECTRIC FURNACES

Levoz. Designs New Electric Furnace, R. Sylvany. Foundry, vol. 50, no. 23, Dec. 1, 1922, pp. 962–963. Principles of construction of furnaces of latest French development, by T. Levoz, employed during war in production of high-speed steel; metal melted in crucible-shaped vessel with only one opening; electrode through roof sheathed to prevent ingress of air.

ELECTRIC MOTORS

Selection and Control. Selection and Control of Motors, Roger B. Stevens. Elec. World, vol. 80, no. 27, Dec. 30, 1922, pp. 1433–1437, 7 figs. Avoidance of service interruptions without trained and expensive maintenance crew and under necessity of operating with common labor was chief problem in Am. Sugar Refining Co.'s plant.

EMPLOYMENT MANAGEMENT

Engineering Department. The Successful Operation of an Engineering Department, W. E. Irish. Indus. Management (N. Y.), vol. 65, no. 1, Jan. 1923, pp. 19–22. Plan of action in dealing with labor. Assembling and operating the "man-machine."

FLOW OF FLUIDS

Electric Measuring Instrument. Electrical Instrument Applied to Measurement of Fluids, E. H. Freeman. Power, vol. 56, no. 26, Dec. 26, 1922, pp. 1008–1009, 2 figs. Electrical integrating instrument developed by author which is practically free from voltage error; adopted by Republic Flow Meter Co., Chicago.

FORGINGS

Nickel-Chrome. Studies Nickel Chrome Forgings, T. Henry Turner. Iron Trade Rev., vol. 71, no. 25, Dec. 21, 1922, pp. 1695–1700, 7 figs. Defects found on machined surfaces of hollow cylindrical bells are traced to ingot corner segregation; investigation showed depth of these segregations extended from 2 to 3 in.: recommendations.

FOUNDATIONS

Power Stations. Foundation and Framing Design of Colfax Power Station, M. E. Thomas. Eng. News-Rec., vol. 89, no. 26, Dec. 28, 1922, pp. 1102–1105, 7 figs. Concrete mat foundation on gravel; column loads distributed by reinforced-concrete walls; special retaining wall and sea wall held by ties.

FOUNDRIES

Ford's River Rouge. Ford Principles and Practice at River Rouge, John H. Van Deventer. Indus. Management (N. Y.), vol. 65, no. 1, Jan. 1923, pp. 11, 23 figs. Plant facilities of world's largest foundry.

GEAR CUTTING

Formed Cutters. Cutting Bevel Gears with Formed Cutters, Franklin D. Jones. Machy. (N. Y.), vol. 29, no. 5, Jan. 1923, pp. 363–365, 6 figs. Brown & Sharp automatic gear-cutting machines of formed-cutter type designed for cutting either spur or bevel gearing.

GRINDING

Automobile Parts. Grinding Data from the Pierce-Arrow Shop, Fred H. Colvin. Am. Mach., vol. 57, no. 26, Dec. 28, 1922, pp. 997–998, 3 figs. Testing cylinder gages; grinding bronze connecting-rod bushings; forming steering balls; grinding aluminum transmission covers.

HYDROELECTRIC DEVELOPMENTS

Western States. Outstanding Features of Western Water-Power Development in 1922. Eng. News-Rec., vol. 90, no. 1, Jan. 4, 1923, pp. 14–16, 2 figs. Forward steps in design and construction; stabilized tendency toward municipal ownership or control; economic aspects of Western water-power situation.

INDUSTRIAL MANAGEMENT

Factory Planning. Factory Planning, H. E. Taylor. Engineering, vol. 114, nos. 2972 and 2973, Dec. 15 and 22, 1922, pp. 756–758 and 786–788, 8 figs. Survey of systems of shop planning for various methods of production. See also Eng. Production, vol. 5, no. 115, Dec. 14, 1922, pp. 557–563, 9 figs.

Machine Jobbing Shop. Management of the Machine Jobbing Shop, H. L. Wheeler. Am. Mach., vol. 58, no. 1, Jan. 4, 1923, pp. 13–18, 1 fig. Distinction between manufacturing and jobbing; systems, operations and methods; how orders are received and handled; what jobbing-shop management should avoid.

Process Planning. Notes on Process Planning. Engineering, vol. 114, no. 2973, Dec. 22, 1922, pp. 778–780, 4 figs. Principal aim when planning sequence of processes is to secure maximum economy of production as a whole.

Production Executives. What the Production Executives Should Know from the Financial Records, William M. Lyband. Management Eng., vol. 4, no. 1, Jan. 1923, pp. 19–23. Coördination of divisional planning and operation; information for foremen; facts in regard to department operation; overhead expenses; spoilage, waste and idleness; reports in shop language; information for production executives; cost of idle equipment and time; operation of inventory; etc.

Quality Control. Quality Products, G. S. Radford. Management Eng., vol. 3, nos. 5, and 6, Nov. and Dec. 1922, pp. 261–266, 3 figs. and vol. 4, no. 1, Jan. 1923, pp. 51–56, 5 figs. Control methods used by leading manufacturers to maintain standards. Answers to questionnaire sent to number of representative firms.

LOCOMOTIVES

Developments 1922. A Year of Innovations in Locomotive Design, A. F. Steubing. Ry. Age, vol. no. 1, Jan. 6, 1923, pp. 41–43, 4 figs. Steam-turbines locomotives in Europe; mechanical draft receiving increased attention.

MACHINERY

Power, Erecting. Erecting Power Machinery Having Cast-Iron Bedplates, N. L. Rea. Power, vol. 56, no. 26, Dec. 26, 1922, pp. 1021–1023, 6 figs. Proper supporting of machine base; preparing top of foundation; handling bedplate; leveling and aligning; grouting bedplate to foundation; assembling machine and putting it in operation.

OIL FUELS

Calorific Value. The Determination of the Calorific Value of Liquid Fuels, H. Moss and W. J. Stern. Engineering, vol. 114, no. 2972, Dec. 15, 1922, pp. 729–731, 6 figs. Experiments undertaken to investigate methods of determining calorific values, with view to evolving one by means of which absolute values for any fuel undergoing engine test could be obtained quickly and accurately.

OPEN-HEARTH FURNACES

Loftus. New Type of Open-Hearth Furnace. Iron Age, vol. 110, no. 26, Dec. 28, 1922, pp. 1677–1679, 5 figs. Loftus furnace involves new way to apply blow-torch principle; details and results of unit operating several months.

PIPE

Stresses in. The Stresses in End-Supported Filled Pipes (Ueber die Spannungen in freitragenden gefüllten Rohren), E. Schwerin. Zeit. für angewandte Mathematik u. Mechanik, vol. 2, no. 5, Oct. 1922, pp. 340–353, 3 figs. Study of influence of bending and torsional strength of pipe wall, not only under stress of liquid, but also under natural weight of pipe itself.

PUMPING ENGINES

High-Head. Hackensack Water Company's High-Head Pumping Engines. Power, vol. 56, no. 26, Dec. 26, 1922, pp. 1006–1008, 4 figs. Vertical, triple-expansion pumps designed to operate against unusually high head of 293 lb. per sq. in., maintain high efficiency over wide range of operating conditions.

RAILWAY MOTOR CARS

Gasoline. Motor Driven Rail Car with High Power Unit. Ry. Mech. Engr., vol. 96, no. 12, Dec. 1922, pp. 697–698, 3 figs. New equipment for Maryland & Pa. has 120-hp. engine and seats 76 passengers.

RAILWAY SHOPS

Shortcomings. What's Wrong with the Railroad Shops? Am. Mach., vol. 57, nos. 17, 20, 23 and 25, Oct. 26, Nov. 16, Dec. 7 and 21, 1922, pp. 677–680, 755–757, 879–881 and 955–957 and vol. 58, no. 1, Jan. 4, 1923, pp. 1–3, 2 figs. Information based on critical survey of situation. Mechanical departments said to be badly handicapped by poor equipment; lack of contact with other shops. Nov. 16: Shop equipment as it is, with suggestions for more efficient use of what is available and replacing obsolete units with new ones. Dec. 7: Small-tool situation; lack of coöperation between mechanical and purchasing departments; inadequacy of tool-sharpening equipment. Dec. 21: Suggestions regarding interchange of information and standardization of parts and methods; cost-keeping systems. Jan. 4: Underlying causes of present shop troubles; how to remedy shortcomings of methods, equipment and personnel.

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Mechanical Engineering

The Monthly Journal Published by

The American Society of Mechanical Engineers

Publication Office, 207 Church Street, Easton, Pa. Editorial and Advertising Department at the Headquarters of the Society, 29 West Thirty-ninth Street, New York

Volume 45 March, 1923 Number 3

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ADVERTISING

Price 50 Cents a Copy, $4.00 a year: to Members and Affiliates, 40 cents a Copy, $3.00 a Year. Postage to Canada, 75 Cents Additional; to Foreign Countries, $1.50 Additional. Changes of address should be sent to the Society Headquarters.

Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879.
Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921.

Contributors and Contributions

The Machine-Tool Industry

E. F. DuBrul

Speakers at a recent joint meeting of the Philadelphia Local Section and the Machine Shop Division of The American Society of Mechanical Engineers, the Engineers' Club of Philadelphia, and the Philadelphia Section of the American Institute of Electrical Engineers, approached the subject of the machine-tool industry from three different angles. Ernest F. DuBrul, Cincinnati, Ohio, discussed some of its economic features, Benjamin P. Graves and James A. Hall, Providence, R. I., the effect of variations in design of milling cutters on power requirements and capacity, and Dexter S. Kimball, Ithaca, N. Y., the development of machine tools.

Mr. DuBrul, who is general manager of the National Machine Tool Builders' Association and president of the Pyro Clay Products Company, was graduated from Notre Dame University and did graduate work at Johns Hopkins University. From 1897 to 1911 he was director and superintendent of the Miller, DuBrul & Peters Mfg. Co., and its president from 1915 to 1919. Mr. DuBrul analyzes costs and compares productivity of large and small shops.

The paper by Messrs. Graves and Hall, setting forth the results of investigations to determine the effect of changes in the design of milling cutters, will be found of great practical value. Mr. Graves is a graduate of the Rhode Island School of Design, class of 1904, where for six years he instructed evening classes in machine-tool design. Since 1915 he has been milling-machine engineer for the Brown & Sharpe Manufacturing Co., in charge of all milling-machine designs and problems, both for shop use and outside sources.

The co-author of the paper, Professor Hall, was graduated from Brown University in 1908 and has been giving instruction and conducting research there since that time. He is now associate professor of mechanical engineering. He is also president of the Providence Engineering Society.

Dean Kimball's address pays tribute to all those who have contributed to the development of machine tools from their crude beginnings to the modern standards of accuracy and output.

Progress in Steam Research

The first record of progress in the research of the properties of steam for the formulation of new steam tables appears in this issue. Dr. R. V. Kleinschmidt gives the results obtained in experiments at Harvard on the Joule-Thomson effect and Dr. Keyes of M.I.T. and Mr. Osborne of the Bureau of Standards tell of the progress made in designing apparatus for the parts of the work they are to carry on. These reports were originally presented at the A.S.M.E. Annual Meeting in December, 1922.

Elasticity of Pipe Bends

Sabin Crocker and Sterling S. Sanford, both of whom are associated with the Detroit Edison Company, have contributed to this issue an article on the elasticity of pipe bends. Both Mr. Crocker and Mr. Sanford were born in Mt. Clemens, Mich., and were graduated from the University of Michigan. Except for their war service they have since been connected with the Detroit Edison Company, where Mr. Crocker is now piping engineer and Mr. Sanford research engineer.

Vocational Training for the Industries

This issue contains a review of the present status of the many types of industrial education which proves that such education has already advanced in a truly remarkable way and promises much for the future. Members of the A.S.M.E. Committee on Education and Training for the Industries who prepared this report are James A. Moyer, Robert L. Sackett, and Charles R. Richards. Professor Moyer was graduated from Harvard University in 1899, and taught engineering, mathematics, and experimental engineering there until 1904. After two years in engineering work for the General Electric Company and one for Westinghouse, Church, Kerr & Co., he reëntered the teaching profession as professor of mechanical engineering at the University of Michigan. In 1912 he transferred to Pennsylvania State College, and since 1915 he has been director of the university extension work of the Massachusetts Department of Education.

Dean Sackett is a University of Michigan graduate, class of 1891. Previous to 1915 he was professor of sanitary and hydraulic engineering at Purdue University, and since that time he has been dean of the school of engineering at Pennsylvania State College and director of its engineering-experiment station and engineering extension.

Professor Richards received the degree of M.E. from Massachusetts Institute of Technology in 1885. He has served successively as director of the Department of Science and Technology, Pratt Institute, director of the Department of Manual Training, Teachers' College, Columbia University, and director of Cooper Union. He has also been special agent of the N. Y. Department of Labor, and was for two years secretary of the National Society for the Promotion of Industrial Education.

Design of Woodworking Machinery

Woodworking machinery of the future will be greatly influenced by such factors as the adoption of high-speed steel, demands of greater economy, power and speed, the use of ball bearings, and the direct application of the electric drive. Sern Madsen discusses these factors in the present issue. He was graduated from the State College at Ames, Iowa, in 1911, receiving his M.E. from that institution in 1916. He was for a time superintendent of maintenance and power for Curtis Brothers & Co., Clinton, Ia., and since 1918 has been superintendent of plant equipment for the Curtis Companies, Inc., of Clinton.

MECHANICAL ENGINEERING

Volume 45 March, 1923 No. 3

Economic Features of the Machine-Tool Industry

Some of the Features Brought Out as a Result of Analyzing the Statistics of the 1919 Census of Manufacturers—Problems of Management—Trade Evils and Their Remedies

By ERNEST F. DUBRUL,[1] CINCINNATI, OHIO

VERY few people give thought to the vital economic fact that without the organizing, imaginative minds of business leaders there would have been little material progress in the world. Those who propose untried industrial systems for dreamlands never think of it at all. Without free play for the adventurous, creative, pioneering spirit of those who can organize and direct industry, the world would soon slip back in its achievements of the comforts and luxuries that it enjoys. Only the joint effort of business brains and mechanical brains keeps us as we are, and pushes us on.

We hear much loose talk about the rich getting richer and the poor getting poorer in these days when the streets are full of poor men's automobiles. By the use of machinery, directed by the organizing minds of business leaders, the productivity of the nation has increased in the last century about twenty times as fast as the population, and cold statistics prove the truth to be that the poor are getting richer with the rich. Progress will continue at an increasing rate, unless stopped by attempts to put in practice such suicidal dreams as have been tried in Russia.

Consider how little of man's work continues in existence for 100 years. Most of it is replaced before worn out by better and more adaptable plant. Even if we made no advances in methods we would have to keep on replacing the old, as the forces of nature soon destroy the handiwork of man. All this requires that some men must look forward many years to a demand from unborn generations.

Only because some men looked far ahead to such demands of our present generation have we the comforts we enjoy. Only because some men could save capital, and do so in reasonable security, are present productive processes giving us these comforts. Only as this generation saves something out of consumption and puts it to work, can future generations have greater comfort.

An impression of the rapid growth in productivity is obtained from comparison of the estimated value of manufactures which in 1812 was $170,000,000 for the United States, whereas in 1919 it was over $62,000,000,000. Of this total, $1^1/_2$ per cent, or nearly one billion, was industrial machinery alone, to say nothing of of electrical equipment, automotive or other vehicles, tractors, agricultural machinery, railway cars, and locomotives. Of the industrial machinery, machine tools form the largest single class and in value it is about twice as large as the next largest class, textile machinery.

Because the blacksmith made the tools for all the other workers who built the temple of Solomon, the legend is that King Solomon honored the blacksmith above all the other workers. The modern machine-tool builder now stands in that blacksmith's place, producing the master tools for all other crafts.

TABLE 1 DATA FROM U. S. CENSUS OF MANUFACTURES, 1919
Reduced to "Per Shop" and "Per Wage-Earner" Basis

	All Industries			Machine Tools		
	Totals	Per Shop	Per Wage Earner	Totals	Per Shop	Per Wage Earner
Number of establishments	290,105	....	......	403	....	......
Average number of wage earners	9,096,372	31	......	53,111	132	......
Nunber of salesmen, clerks, etc	1,033,507	5	......	6,186	15	......
Number of superintendeots aod managers	281,253		......	1,696		......
Number of corporation officers	132,467	2	......	637	5	......
Number of proprietors	269,137		......	132		......
Total number of persons engaged	10,812,736	38	......	61,762	152	......
Capital employed	$44,558,593,771	$153,594	$4,898	$231,039,843	$573,298	$4,350
Turnover	140	......	....	92	......	....
Value of product	$62,418,078,773	215,156	6,862	212,400,158	527,047	3,999
Material used	35,730,393,727	123,163	3,927	56,048,334	139,077	1,055
Fuel and power rented	1,645,986,556	5,674	180	2,985,974	7,409	56
Value added by manufacturer	25,041,698,490	86,319	2,753	153,365,850	38,056	2,887
Wages paid	10,533,400,340	36,308	1,157	66,178,969	164,215	1,246
Salaries paid	2,892,371,494;	9,971	318	18,037,856	44,759	340
Contract work	464,403,700	1,601	51	1,469,844	3,648	28
Rents	212,043,089	731	23	476,353	1,182	9
Taxes—federal	1,790,197,060	6,170	197	15,755,796	39,096	296
Taxes—state	289,172,297	997	32	2,083,106	5,169	39
Tot. (Deductions from Av.)	$16,181,587,980	$ 55,578	$1,778	$104,001,924	$258,069	$1,958
Residue	8,860,110,510	30,541	974	49,363,926	122,491	929
Interest on capital at 7 per cent	3,119,101,563	10,752	343	16,172,789	40,130	304
Net residue	$ 5,741,008,947	$ 19,789	$ 631	$ 33,191,137	$ 82,361	$ 625

I shall give you an outline picture of the machine-tool industry through some analysis of the statistics of the Census of Manufactures of 1919. This census gives the number of establishments, capital employed, value of product, costs of material, fuel, power, wages, salaries, contract work, rents, taxes, number of wage earners and salaried employees. To get our first comparison we reduce this data to a "per shop" basis, and also to a "per wage earner" basis as set forth in Table 1.

From the "per shop" figures we see that the average machine-tool shop is about four times as large as the average of all industries, as shown by the items of capital, number of wage earners, added value, wages, salaries, etc.

The size of his shop shows the machine-tool man to be a good manager, and some other things confirm this. He paid his men better than the average employee got elsewhere, but his salary roll was less in proportion and the number of supervising personnel also smaller in proportion. While salaries formed 27.3 per cent of the payroll of the average shop, they show as only 21 per cent of the payroll of the machine-tool shop.

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Presented at a joint meeting of the Philadelphia Local Section and the Machine Shop Division of The American Society of Mechanical Engineers, the Engineers' Club of Philadelphia, and the Philadelphia Section of the American Institute of Electrical Engineers, Philadelphia, February 27, 1923. Slightly abridged.

TABLE 2 DISTRIBUTION BASED ON VALUE ADDED BY MANUFACTURE AS 100 PER CENT

	All Industries		Machine Tools	
		Per cent		Per cent
Value added by mfr.	$25,041,698,490	100	$153,365,850	100
Capital employed	44,558,593,771	177	231,039,843	150
Value of product	62,418,078,773	249	212,400,158	138
Material used	35,730,393,727	142.5	56,048,334	36.5
Fuel and power rented	1,645,986,556	6.5	2,985,974	1.5
Wages paid	10,533,400,340	42.1	66,178,969	43 2
Salaries paid	2,892,371,494	11.6	18,037,856	11 8
Contract work	464,403,700	1.9	1,469,844	1.0
Rents	212,043,089	0.8	476,353	0.2
Taxes—federal	1,790,197,060	7.1	15,755,796	10.3
Taxes—state	289,172,297	1.2	2,083,106	1.4
Residue	8,860,110,510	35.3	49,363,926	32.1
Interest on cap. @ 7%	3,119,101,563	12.4	16,172,789	10.5
Net Residue	$ 5,741,008,947	22.9	$ 33,191,137	21.6

TABLE 3 DISTRIBUTION BASED ON VALUE OF PRODUCT AS 100 PER CENT

	All Industries		Machine Tools	
		Per cent		Per cent
Value of product	$62,418,078,773	100	$212,400,158	100
Capital employed	44,558,593,771	71.4	231,039,843	108.7
Material used	35,730,393,727	57.3	56,048,334	26.3
Fuel and power rented	1,645,986,556	2.6	2,985,974	1.4
Value added by mfr	25,041,698,490	40.1	153,365,850	72.3
Wages paid	10,533,400,340	16.9	66,178,969	31.2
Salaries paid	2,892,371,494	4 6	18,037,856	8.5
Contract work	464,403,700	0.7	1,469,844	0.7
Rents	212,043,089	0.3	476,353	0.3
Taxes—federal	1,790,197,060	2.9	15,755,796	7.4
Taxes—state	289,172,297	0.5	2,083,106	1.0
Residue	8,860,110,510	14 2	49,363,926	23.2
Interest on cap. @ 7%	3,119,101,563	5.0	16,172,789	7.6
Net Residue	$ 5,741,008,947	9.2	$ 33,191,137	15.6

The item of added value is the index of manufacturing activity. This item excludes material from the total value. The manufacturer's function is to convert material into finished product. Of this added value the machine-tool salary roll was only 11 per cent while the average was 16 per cent, so evidently he was not extravagant in that particular.

After taking out of the total value all the amounts specified, there still remains a balance, designated as "residue" for want of a better term. As the census figures do not go into further detail, we can only say that this residue still includes costs like depreciation, obsolescence, insurance, advertising repairs, interest, legal, patent, auditing, traveling, and all other expenses not covered by the specific expenses mentioned. It would be proper to deduct from this an allowance for interest on capital which in 1919 at the going rate was easily 7 per cent. This would allow the average shop $19,720 and the machine-tool shop $82,361. From the "per wage earner" figures we note that the machine-tool builder used $600 less capital than the average.

TABLE 4 FIGURES CLASSIFIED ACCORDING TO SIZE OF SHOPS

	Machine Tools					
	All Shops	$20,000 & Under	$20,00 to $100,000	$100,000 to $500,000	$500,000 to $1,000,000	Over $1,000,000
No. of establishments	403	66	110	134	41	52
Per cent	100	16.4	27 3	33.2	10.2	12.9
No. of wage earners	53,111	245	1,941	8,162	7,235	35,528
Per cent	100	5/10	3.7	15.3	13.6	66.9
Per shop	132	4	18	61	176	683
Capital { Distributed by % Val. of Product	$231,039,843	$693,120	$6,469,116	$34,655,976	$30,266,219	$158,955,412
Per cent	100	3/10	2.8	15	13.1	68.8
Per shop	573,298	10,500	58,810	258,634	738,200	3,056,834
Per wage earner	4,350	2,829	3,332	4,246	4,183	4,474
Value of product	212,400,158	615,394	6,026,556	31,759,941	27,856,054	146,142,213
Per cent	100	3/10	2.8	15	13.1	68.8
Per shop	527,047	9,324	54,786	237,015	679,415	2,810,427
Per wage earner	3,999	2,511	3,105	3,891	3,850	4,113
Materials & power	59,034,308	230,752	2,049,589	10,271,346	7,846,590	38,636,031
Per cent	100	0.4	3.5	17.3	13.2	65.6
Per shop	146,486	3,497	18,632	76,651	191,380	743,000
Per wage earner	1,111	942	1,055	1,258	1,085	1,087
Value added by mfr	153,365,850	384,642	3,976,967	21,488,595	20,009,464	107,506,182
Per cent	100	0.3	02.6	14	13	70.1
Per shop	380,561	5,858	36,154	160,385	488,035	2,067,426
Per wage earner	2,887	1,570	2,048	2,632	2,765	3,025
Wages { Distributed by % No. of W. E.	66,178,969	304,423	2,415,532	10,165,090	9,020,194	44,273,730
Per shop	164,215	4,613	21,960	75,858	220,000	851,418
Per wage earner	1,246	1,246	1,246	1,246	1,246	1,246
Remainder { For Expense and Profit	87,186,881	80,219	1,561,435	11,323,505	10,989,270	63,232,452
Per cent	100	1/10	1 8	12.7	12.8	72.6
Salaries (Distributed by % of Remainder for Expense and Profit)	18,037,856	18,038	324,861	2,290,808	2,308,845	13,095,484
Contract W. H.	1,469,844	1,470	26,457	186,670	188,140	1,067,107
Rents	476,353	476	8,574	60,496	60,974	345,833
Taxes—federal	15,755,796	15,755	283,605	2,000,986	2,016,742	11,438,708
Taxes—state	2,083,106	2,083	37,496	264,554	266,638	1,512,335
Total	$ 37,822,955	$ 37,822	$ 680,813	$ 4,803,514	$ 4,841,339	$ 27,459,467
Per shop	93,853	573	6,189	35,847	118,081	528,067
Per Wage earner	712	154	350	588	669	772
Residue	49,363,926	42,397	880,622	6,519,991	6,147,931	35,772,985
Int. on capital @ 7%	16,172,789	48,518	452,838	2,425,919	2,118,635	11,126,879
Net Residue	$ 33,191,137	—6,121	$ 427,784	$ 4,094,072	$ 4,029,296	$ 24,646,106
Per cent	100	0	1.3	12.4	12.1	74.2
Per shop	82,360	—92	3,889	30,552	98,275	473,963
Per wage earner	624	—24	220	501	556	693

TABLE 5 RATIO OF ALL ITEMS TO TOTALS, PER CENT

	All Industries						Machine Tools					
	Totals	20M & Under	20M to 100M	100M to 500M	500M to 1000M	Over 1000M	Totals	20M & Under	20M to 100M	100M to 500M	500M to 1000M	Over 1000M
No. of establishments	100	52 7	26.8	13.7	3.2	3 6	100	16.4	27.3	33.2	10.2	12.9
No. of wage earners	100	3 2	8 7	18 9	12.3	56 9	100	0.5	3 7	15.3	13.6	66.9
Capital employed	100	1.8	5 7	14 4	10.4	67.7	100	0.3	2.8	15 0	13.1	68.8
Value of product	100	1.8	5.7	14.4	10.4	67.7	100	0.3	2.8	15 0	13.1	68.8
Material & power	100	1.2	4.9	13.0	9.6	71.3	100	0.4	3.5	17.3	13.2	65.6
Value added by mfr	100	2.6	7.0	16.6	11.5	62.3	100	0.3	2 6	14.0	13.0	70.1
Wages paid	100	3 2	8 7	18.9	12.3	56.9	100	0.5	3.7	15.3	13.6	66.9
Salaries, rents, Contract wk. Taxes—federal & state	100	0.1	1.8	12.7	12.8	72.6	100	2.1	5.7	14 9	11.0	66.3
Residue (net)	100	2.3	5.8	15.2	11.2	65.5	100	0.	1.3	12.4	12.1	74.2

The average manufacturer took $4100 worth of material and fuel per wage earner in 1919, and by processing added to it $2752 worth of utility, or 66 per cent. But the creative machine-tool builder took $1100 of material per wage earner and added $2887 or 262 per cent of utility to it. As the real function of all manufacturers is to add utility, it would seem fair to compare them by using, as a base, the value added. Table 2 reduces the various factors to a percentage of this base. From this we deduce that to produce $100 of added value at the market price of his goods, the average manufacturer employed $177 of capital against the machine-tool builder's $150. The average used $149 of material against the machine-tool builder's $38. It cost them both about the same in expenses specified, except that Federal taxes took $3 more out of the machine-tool builder. If now we allot 7 per cent interest on the capital invested in each case, the average manufacturer got a net residue somewhat greater than the machine-tool builder.

Table 3 gives the various components of total value, and shows the machine-tool builder as having a larger percentage of residue.

Table 4 is an attempt to get the residue down to a "per wage earner" basis, by classes according to the size of the establishment. Deducting wages from added value shows a still greater concentration of the remainder in the large shops. We next distribute the salaries, taxes, etc., in proportion to this last balance. This is overloading the small shop with Federal taxes that it may not have paid, as its earnings were smaller per man and it had an exemption of $2000. On the other hand, there is some counterbalance to this overload, because the overhead per wage earner is larger in the small shops than in the large ones. This is true in spite of the notions of many proprietors of small shops and officers of small corporations who do not pay themselves the salaries they could earn elsewhere, and thereby deceive themselves into thinking their overhead is low. On the whole, the method here used probably gives them a better showing in wages, in expense items, and in residue per wage earner than the facts warrant.

From these figures some interesting suggestions arise as to machine-tool builders. Note the small residue per wage earner left in

shops below the $100,000 line, which is not enough to pay interest, to say nothing of allowing for other expenses and profit. The men who have these small shops seem to be taking a very long chance that they can ill afford to take. Yet 44 per cent of the machine-tool builders were doing that very thing

It is worth noting that although machine-tool shops must employ a highly skilled force of wage earners, and their force is larger in each class than the average, still in each class the residue per wage earner was less than the average, though this residue increases with the size of the shop, as we would expect.

Table 5 throws some interesting light on the concentration of industry in large establishments. The net residue percentage for each class compared to the percentage of number of establishments would indicate that while a larger proportion of machine-tool shops are in the million-dollar class, and while the proportion of net residue is also higher in this class of machine-tool shops than for all industries, the relative concentration is over three times greater in all industries than in the machine-tool industry.

Table 5 shows that while small shops are numerous, the greatest bulk of production is effected in shops turning out $1,000,000 worth of product or more. While the shops turning out less than $100,000 per year are nearly 80 per cent of the general total, they employ only 12 per cent of the wage earners, to say nothing of the mass of proprietors, etc., not listed as wage earners. Then they succeed in producing less than 10 per cent of the added value. The small machine-tool shops, almost 44 per cent of the number, produce only 3 per cent of the added value with their proprietors and 4 per cent of the wage earners.

Note the concentration of 70 per cent of the added value in about 13 per cent of the machine-tool shops that averaged $2,000,000 of added value and $3,000,000 of capital. Nobody ordered this concentration, it developed very naturally. Consolidations have been very few in the industry; it got its million-dollar shops, its half-million dollar shops and its hundred-thousand dollar shops by grinding thrift and hard work.

The high level of management in the machine-tool business is indicated by the fact that 13 per cent of the machine-tool builders are in the $2,000,000 group of value adders, whereas only 3½ per cent of the average manufacturers are in the $500,000 class. Moreover 10 per cent of the machine-tool men are in the $500,000 class compared to 3 per cent of average manufacturers in the $300,000 class. Again, 33 per cent of machine-tool men are in the $250,000 class, while only 13 per cent of average manufacturers are in the $100,000 class. And only 44 per cent of adventurous machine-tool builders are in the two lower classes compared with 79 per cent of all manufacturers in those classes, and the figures seem to indicate that such small shops must have very hard sledding in the machine-tool business.

Problems of Management of Machine-Tool Shops

The fluctuating nature of the demand for machine tools creates serious problems in different stages of the business cycle. It is evident that the more regular an industry's demand, the lower can be its costs and the easier its managerial problems. The peculiarities of human nature as manifested in business cycles compel the builder of machine tools to face relatively short and sharp peaks of activity, followed by relatively long and deep depressions. The industry has a naturally bad load factor for some very human reasons. The first is that most people do not look very far ahead, and most machine-tool users are no different in that particular. Therefore, comparatively few users forecast their machine-tool requirements to any great extent. In a period of depression the user's shop is more or less idle, and he has more than enough machinery to supply the restricted demand for his own goods. He is mentally so depressed by dull business that he cannot bring himself to even think of a time just a few months ahead when his business will be more active, when the natural growth of population and wants will demand more of his goods than he was able to make in his last boom. Not forecasting what the future has in store, and how long the depression in his own business will last, he simply will not spend money on plant improvements when he could be making them to the best advantage.

Consider now the difficulties of the machine-tool builder in trying to regulate his operations. At the height of his own previous boom he had as full a force of men as he could get, working night and day. He had also a lot of contracts out for castings and other material, placed far in advance, in large quantity, at high prices, to be able to supply his customers' wants without delay. Even though he had been quoting six to eighteen months' delivery, his orders had been piling in on him with increasing speed. When his orders began to fall off he had this large impending inventory thrown on his shoulders. Then he got many cancellations, from those who should have been compelled to live up to their contracts. If he was unwise enough to accept them he was stuck with large inventories in all stages of completion, but without sale.

Being of the adventurous rather than of the prudent type, and of the inventive rather than of the commercial turn of mind, he had not given much consideration to the progress of the business cycle. As the economics of the cycle had not been pointed out to him, he did not realize that his industry is among the first to slump in a cycle, and that the slump in machine-tool orders is merely one of the signs of coming trouble elsewhere. He took counsel of hope rather than of prudence. It had cost him so much in money and effort to get his working force together that he hated to break it up. If his product was not of a type built only to order, he kept on working and built stock instead of shutting down his plant. Then, too, he had a goodly share of that human sympathy that leads any decent employer to keep his men employed as long as possible rather than to throw them out of work. Looking back now he realizes that it would have been better both for his men and for himself to have shut down as his orders were filled, and to have waited to build his stock at the bottom of the depression rather than at the crest of a boom.

When his own financial strength was threatened, even the most adventurous and sympathetic could no longer keep on producing, at high costs, machines for which there was no sale at any price. So the industry finally had to do late what it should have done early in the slump, that is, shut down and wait for improvement in conditions in other lines to revive demand for machine tools.

Not only is the period of carry over likely to be long, but another danger of carrying large stocks must be reckoned with. That danger lies in obsolescence of designs. Necessity is the mother of invention, and the necessity of getting work for idle shops always produces a good-sized family of new and improved designs after a depression has been on for some time. When these are brought forth, their greater utility to the user kills the demand for the older types. In a depression, machines of new design can generally be made for less than the old types had cost in the boom. Even if not obsolescent the replacement cost of the older type is less in a depression that it was in the boom. Some competitor who has no knowledge of unchangeable economic facts is almost certain to hatch the bright idea that by making very low prices while his competitors are asleep, he can get a much larger participation out of a dull market than his natural participation had been in a more active market. He thinks he can thereby carry some of his overhead at their expense. But as the competitors are not asleep, this bright idea fails to get the anticipated results. All have a natural desire to keep their own places in the sun and they meet his low prices and all get that much less to carry overhead with. While all these factors lead to great losses in a depression, the low prices do not lead to much, if any, stimulation of sales.

For 15 months in the last two years machine-tool-sales volume was down to less than 15 per cent of what it had been in the first quarter of 1920. For 32 months past the demand has averaged about 23 per cent of that figure. In some cases prices were made that would just about cover material and labor, in attempting to coax out orders enough to hold a force of good men together. Some people think that because demand for cheap automobiles can be stimulated by slight reductions in price, the demand for machine tools acts in the same way. The cheaper the automobile, however, the wider is the stratum of demand it can tap, until a saturation point is reached.

Because of these long periods of depression through which the machine-tool builder must carry his plant and organization, he must put a heavy stand-by charge on his goods. He must cover this cost of necessary idleness—over which he has no control—by accumulating a reserve in good times out of which to draw in bad

(*Continued on page 200*)

The Development of Machine Tools

By DEXTER S. KIMBALL,[1] ITHACA, N. Y.

IN THESE days of many books and much learning we are prone to overlook or forget the fact that man's upward progress in all times has been dependent primarily upon the tools and mechanical appliances at his command. Originally little better than the beasts of the field, man lifted himself from their company by discovering the use and control of fire, and with the invention of the bow and arrow he began to assume his lordship over all created living things. The ability to make pottery advanced him from savagery to barbarism, and the domestication of animals gave him a supply of physical strength far greater than his own to assist him in conquering an unfriendly environment.

The ability to smelt copper and tin into bronze gave him tools and weapons of greatly increased efficiency and enabled him to establish himself securely in permanent habitations where he could till the soil, tend his herds, and have some leisure for thought. From this opportunity to think came the alphabet and written language, and with this ability to record and transmit his thoughts came civilization. Finally the discovery of iron and steel and of almost unlimited power from coal and water power have enabled this master animal to push his ideas of civilization to a height undreamed of by his ancestors, and it has not been possible to predict what the end may be.

Man is distinguished, therefore, from other inhabitants of the animal world principally by his power to make and use tools and with their aid to subdue his physical surroundings to satisfy his needs. These tools are of two distinct kinds. First come those that he has developed to supplement his own puny strength and to increase his effectiveness. The story of the development of power-supplying devices from the first crude hatchet to the monster power stations of today is in itself an epic unequaled by anything else except, perhaps, the parallel development of the art of transmitting intelligence. The story of man's progress from signaling with fire or smoke to modern radiotelephony is without doubt man's most spectacular achievement as it is also one of his most useful accomplishments.

But a supply of power of itself alone would not have been sufficient for man's needs. Methods of utilizing and guiding this power so that it would perform useful work were essential requirements for progress. Of a necessity machines were needed that would perform the operations of industry as well or better than they could be performed by the human hand. The second great division of this field, therefore, comprises the tools that involve "transfer of skill." Practically all tools that are actually used in productive processes involve this principle. The stone ax, the bow and arrow, and all handicraft tools have come into being in answer to a desire on the part of some one to improve his product in quality or quantity by the aid of some one of these implements.

Until the middle of the eighteenth century the use of tools as then developed still required a considerable degree of skill on the part of those operating them. The tool was still only an adjunct to the skill of the worker. About that time, however, a series of interesting inventions demonstrated the possibility of making machines involving such a large transfer of skill as to make the worker an adjunct to the machine in many industrial processes. This is the essence of the Industrial Revolution, so called, and today automatic machines that perform the necessary operations with little or no human aid are in common use.

Back of the amazing array of productive tools and processes that now fill the land, stand a group of tools that are in a class by themselves. These may be called the "Master Tools of Industry" since the production of all other tools and processes, in the construction of which metal working is a necessity, depends upon the possession of some or all of these tools. This group consists of the lathe, the planer, the drilling machine, the boring mill, the milling machine, and the grinding machine, with their several modifications and derivatives. They constitute the group commonly known as "machine tools" and are familiar to all who are acquainted with machine production. This group of tools are worthy of special notice for they are basic implements and, as formerly remarked, accurate machine construction of all kinds depends absolutely upon them.

The primitiveness and inaccuracy of the machine tools in use when Watt began to build his steam engines are almost unbelievable. We find him complaining of one of his steam cylinders that "at the worst place the long diameter exceeds the short by three-eighths of an inch" and there is much other evidence that indicates similar crudity in all machine processes. The development from these crude beginnings to the modern standards of accuracy and output is something of which every engineer may well feel proud. It is difficult always to give due credit for great improvements in any line to all who have contributed to the accomplished result. Great inventions, so called, are usually the result of a long train of thought and experiment on the part of many men. But it is customary to give the greatest credit to the man who first makes a great idea a real working possibility. For this reason there are a few outstanding men among those who brought this great change about, though undoubtedly the ideas they put into practical working machines had occupied the minds of many of their predecessors. Wilkinson's boring machine solved Watt's difficulties so that Boulton writes of a fifty-inch cylinder that "does not err the thickness of an old shilling in any part." And there are many other names among these old pioneer English mechanics that should be held in everlasting remembrance when the names of all great warriors have been forgotten.

Outstanding Names in Machine-Tool History

There are, in the history of machine-tool development, three names that stand out in bold relief. The first of these is Henry Maudslay, who was born in 1771. Of the many inventions and improvements in machinery that came from this master mind the most important is the slide rest and its combination with the lead screw and change gears whereby threads could be machined. Until Maudslay's time the turning of metal had been accomplished by hand tools. In fact, this method persisted for many years after his day and there is now preserved in the rooms of The American Society of Mechanical Engineers a turning tool that was used by the late John Fritz not so many years ago. Maudslay finished the sides of his lathe bed and mounted upon it a saddle exactly as used on modern lathes, this saddle carrying a cross-slide in which the tool was rigidly held. The saddle was actuated by a lead screw and change gears as in all modern lathes. As Professor Roe truly says, "Too much value cannot be placed upon the slide rest and its combination with a lead screw operated by change gears. It is used in some form in almost every machine tool and is one of the great inventions of history." Maudslay's improvements constituted a transfer of skill that did much to start the modern industrial era.

The second great improvement in machine tools was the application of the turret to the slide rest so that a series of operations can be performed repeatedly without resetting the cutting tools. Here again we have an idea that was undoubtedly an old one; but it remained for an American, Henry David Stone, to make it a working possibility in the turret lathe built by him in 1858. Stone's first semi-automatic turret lathe carried four cutting tools on the cross-slide and six in the turret. His improvements rank in importance with those of Maudslay and they made possible most of the modern semi-automatic machine tools. Lastly came the invention of the universal cam or "brain wheel" by another American, Christopher Mines Spencer, which provided an automatic control for the combination of Maudslay's slide rest and Stone's

(Continued on page 168)

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Presented at a joint meeting of the Philadelphia Local Section and the Machine Shop Division of The American Society of Mechanical Engineers, the Engineers' Club of Philadelphia, and the Philadelphia Section of the American Institute of Electrical Engineers, Philadelphia, February 27, 1923.

Effect of Variations in Design of Milling Cutters On Power Requirements and Capacity

A Study of the Effect of Changes in the Number of Teeth, Spiral Angle, Rake Angle, and Cutting Speed of the Cutter on Power Consumption, Tendency to Chatter, and Stresses Set Up in the Machine

By BENJAMIN P. GRAVES[1] and JAMES A. HALL,[2] PROVIDENCE, R. I.

THE rapid development of the milling machine during the last two decades into a leading position in heavy machine work has brought about many improvements in the design of milling cutters. The old cutters with many teeth, no rake angle and a small spiral angle were very inefficient from a power standpoint, and it was only about twelve wears ago, following the delivery of a paper before the Society on Milling Cutters and Their Efficiency by A. L. DeLeeuw,[3] that "coarse-tooth" cutters having few teeth, a moderate rake angle, and a much larger spiral angle began to replace the earlier type.

While these cutters rapidly came into almost universal use for production work, little further was done to put the subject on a scientific basis until 1921 when the report of an elaborate piece of research work was presented before the annual meeting of the Society by Prof. John Airey and Carl J. Oxford.[4] Some of the conclusions which they presented differed so greatly from present practice that it seemed desirable to undertake a series of investigations at the plant of the Brown & Sharpe Mfg. Co. to determine the effect of changes in the design of milling cutters. The results obtained are presented in this paper, which comprises a study of the effect of changes in the number of teeth, spiral angle, rake angle, and cutting speed of the cutter on power consumption, tendency to chatter, and stresses set up in the machine.

Choice of Methods

The first consideration in the choice of methods to be followed was that all tests as far as possible should be made under actual shop conditions, using, however, sufficient refinement of measurement to give a high degree of accuracy in the results. On the other hand, as cutters and not machines were to be compared, any variables due to the machine alone must be eliminated. It therefore seemed best to make most of the tests with the work held rigidly on the milling-machine table and to determine the power used by the cutter from the figures of the input into the motors driving the machine.

An old-style Brown & Sharpe No. 3 heavy plain milling machine with a constant-speed drive shaft was available for the tests. Upon the table of this machine a fixture was placed into which dovetailed steel specimens 6 in. wide and 18 in. long could be fastened by mean of a gib. This made about as rigid a means of support as could be devised. The cutters were also rigidly held as they were keyed on to a $1^1/_2$-in. arbor, arbor supports were used on both sides of the cutter, and the outside braces were bolted during all of the tests. In this way errors due to distortion or vibration in the machine or arbor were eliminated as far as possible.

Measurement of Power Used by Cutter

The power figures desired in making comparisons between cutters are the amounts required by the cutters alone and should not include the friction losses in the machine unless the friction has some direct relation to the pressure exerted or power required by the cutter. The problem is complicated by the fact that the power delivered to the milling machine is divided between a slow-moving table and a cutter running at a relatively high speed. Furthermore, these two drives are of widely different efficiencies.

The first step toward getting definite information concerning power requirements was obviously to drive the spindle and table by separate motors. A prony brake was then placed on the arbor and a series of tests run to get the efficiency of the spindle drive at different capacities and speeds. The power input required to run the arbor at no load varied slightly with the speed and condition of lubrication. The brake-horsepower output, however, was always nearly the same for any added kilowatt input over the no-load reading. A horsepower-kilowatt curve was then drawn where the power delivered to the arbor was one coördinate, and the difference between the no-load kilowatt reading and the reading under load the other. One objection to the above method might be that the pressures between the arbor bushings and arbor supports are much greater under cut than on a prony-brake test and that the authors have charged this friction loss to the cutter. However, not only is this a very small amount but it is one that is properly charged to the cutter rather than to the machine.

The proper treatment of the power required by the table is a more difficult problem. Here the no-load kilowatt reading includes the motor losses and the friction losses in all of the bearings up to the table clutch, and these losses remain nearly constant for all loads. The additional power required when the table is operating under load is not only that needed to overcome the pressure of the cutter, but a much greater amount due to the friction loss in the lead screw and thrust bearing caused by that pressure. As this friction varies with the pressure, it seems obvious that it should be charged against the cutter if conditions calling for different pressures are to be compared. The authors therefore took as the net power required by the table the difference between the motor output under load and that when driving the feed mechanism alone.

Any milling-machine table drive is necessarily of low efficiency due to the fact that the table must not continue to move and drive the lead screw after the table clutch is thrown out. This limits the efficiency of the drive to a reasonable margin of safety below 50 per cent when operating on a high-speed return and of course gives a much lower figure at cutting speeds. This low efficiency makes little difference under ordinary conditions as a very small proportion of the total power of the machine is taken by the table. This would be changed if the practice of using low cutting speeds were carried to an extreme. Considerable attention was paid to this condition in the tests and it is further discussed later in the paper.

Cutters

High-speed-steel cutters $3^1/_2$ in. in diameter were used on practically all of the tests, the only exception being a few tests with two 6-in. side milling cutters. All of the $3^1/_2$-in. cutters used in the tests to determine the effect of the number of teeth had 30-deg. spiral angles and 10-deg. rake angles. As the formula derived by Professor Airey and Mr. Oxford called for 20 teeth in such a cutter, this was put at one end of the series, a Brown & Sharpe standard cutter with eight teeth came in the middle, and a four-tooth cutter was added to give an extreme condition of coarse spacing. A number of tests were also made with a 10-tooth cutter. Additional comparisons were made between the two 6-in. side milling-cutters, one of which had 12 teeth and the other 26 teeth, or two less than given by the formula mentioned above. The latter cutter was $^{15}/_{16}$ in. wide and the former 1 in., but otherwise they were exactly alike.

Other sets of cutters alike in every particular except the element to be studied were used in the tests to determine the effect of variations in spiral angle and rake angle. The sizes of these cutters are given in the discussion of the results.

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[2] Associate Professor of Mechanical Engineering, Brown University. Assoc-Mem. Am.Soc.M.E.

[3] Trans. Am.Soc.M.E., vol. 33 (1911), p. 245.

[4] The Art of Milling, Trans. Am.Soc.M.E., vol. 43 (1921), p. 549.

Presented at a joint meeting of the Philadelphia Local Section and the Machine Shop Division of The American Society of Mechanical Engineers, the Engineers' Club of Philadelphia, and the Philadelphia Section of the American Institute of Electrical Engineers, Philadelphia, February 27, 1923. Slightly abridged.

Metal Used in the Tests

As the only object of the investigation was to compare cutters, mild steel was used in all the tests. This was done to enable the authors to make enough cuts to be sure of their results and to eliminate as far as possible variations due to lack of uniformity in the metal being cut. Fortunately most of the tests were made on blocks which were fairly uniform. The tabulation of the figures on the study of spiral angle, however, showed certain unexpected results occurring somewhat uniformly throughout the tests. A little later a cut was taken along the full length of the 18-in. block, the depth, feed, and speed being held constant throughout. The average power required was about six horsepower and the maximum variation was over seven per cent. A repetition of this cut gave the same variations at the same places, showing that it was not accidental. In the authors' studies enough tests had been made so that the average gave results which could be reasonably depended upon. However, this shows how much faith can be placed on the results of tests to determine small variations in power unless a considerable number of runs are made or unless steps are taken to eliminate the effect of these variations on the results.

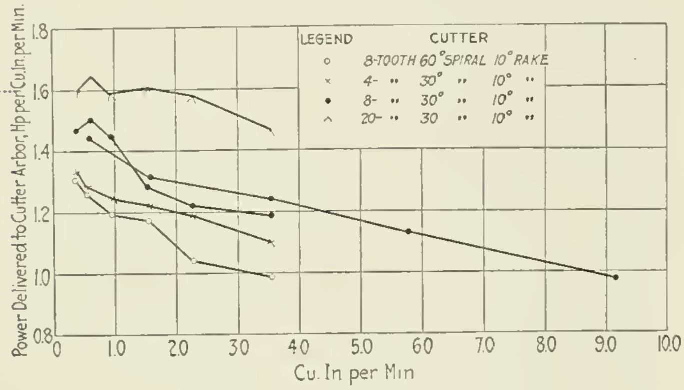

Fig. 1 Power Required By Coarse- and Fine-Tooth Cutters—Constant Depth of Cut and Variable Feed

(Material cut, mild steel; width of cut, 5.5 in.; depth of cut, 0.100 in.; cutting speed 94 ft. per min.)

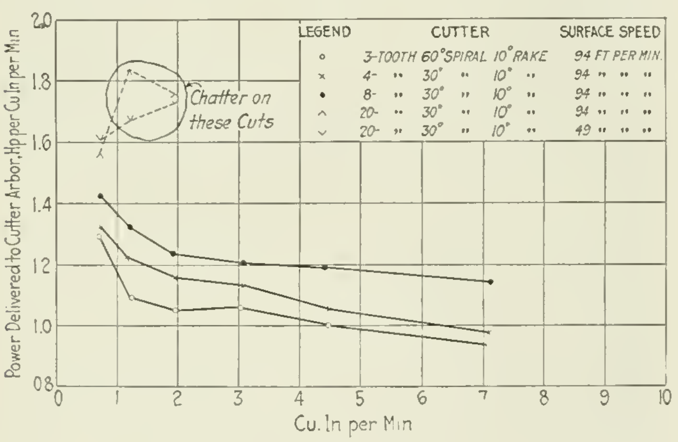

Fig. 2 Power Required by Coarse- and Fine-Tooth Cutters—Constant Speed, Constant Depth of Cut, and Variable Feed

(Material cut, mild steel; width of cut, 5.5 in.; depth of cut, 0.200 in.)

The properties of the steel in all the specimens used in the tests were about the same with the exception of the $^1/_2$-in. bar. The values for tests on specimens 0.505 in. in diameter and 2 in. long are given below:

	$^1/_2$-in. Bar	Other Specimens
Elastic limit, lb. per sq. in.	50,300	42,000
Breaking load, lb. per sq. in.	73,500	68,000
Elongation, per cent	34	35
Reduction of area, per cent	62	62
Brinell hardness	126	126

Method of Making Tests

A light cut was always taken along the specimen before starting any test to guarantee that the depth of cut would be constant. The table was then fed up the desired amount, and from two to six tests were made at this depth of cut in the 18 in. of length of the block. At the end of the first cut the table was run back and the depth of cut checked. The exact figure for the feed was determined by taking the time with a stop watch and measuring roughly the distance traveled with a steel scale and correcting this figure to the thousandth of an inch by reading the dial on the lead-screw handwheel. In this way the exact amount of metal removed per minute was determined.

The electrical instruments were carefully calibrated before starting the investigation and found to be practically correct over their whole range. Before and after each test, readings were taken to determine the friction load and several readings were made during the test to determine if the power remained constant. The differences between the readings under load and the no-load figures multiplied by the proper constants gave the horsepower delivered to the cutter arbor and to the table lead screw.

A number of tests were also made on a special fixture to measure horizontal and vertical pressures by use of two Kenerson traction dynamometers. This was mounted on the table of the machine and calibrated in position by the application of known weights. The method of making these tests was exactly the same as in the others

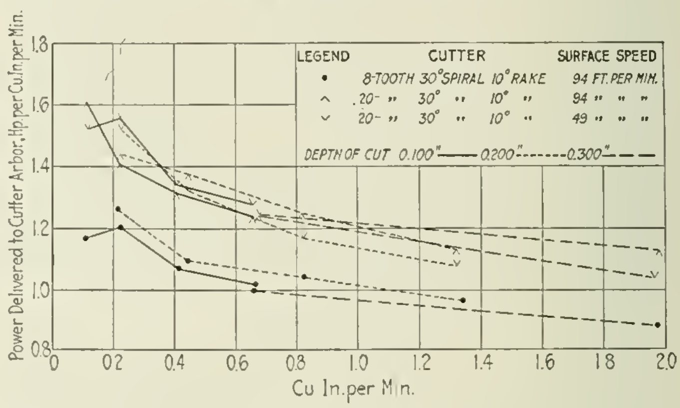

Fig. 3 Power Required by Coarse- and Fine-Tooth Cutters—Constant Speed, Variable Feed

(Material cut, mild steel; width of cut, 1.012 in.; depth of cut, 0.100 in. to 0.300 in. as indicated in figure.)

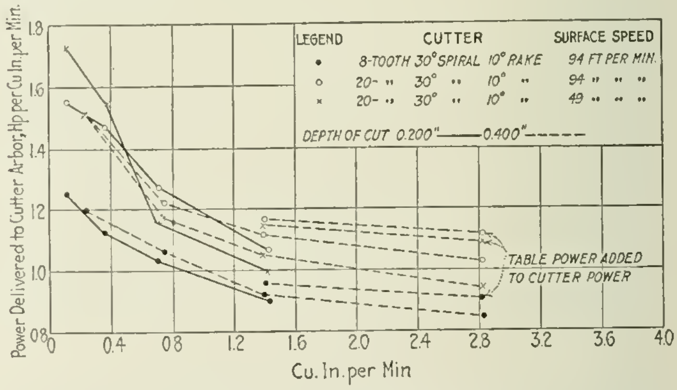

Fig. 4 Power Required by Coarse- and Fine-Tooth Cutters—Constant Speed, Variable Feed

(Material cut, mild steel; width of cut, 0.535 in.; depth of cut, 0.200 in. and 0.400 n. as indicated in figure.)

except that the reading of two dynamometers was added. For moderate cuts this apparatus combined in a high degree rigidity and accuracy, and gave some very interesting results.

As far as possible comparative tests on different cutters were made on the same block of steel and their order was arranged so that corresponding runs came as nearly as possible at similar positions on the the block. In this way errors due to lack of uniformity in the metal were reduced to a minimum.

The results are plotted in the form of curves having as one coordinate either horsepower per cubic inch per minute or pressure along the table. The former figure is used instead of the more common cubic inches per horsepower, as in some cases the sum of the cutter and table power is given as well as the cutter power

alone. For the other coördinate cubic inches per minute, feed per tooth, or maximum chip thickness are used. The latter quantity was used extensively in the paper by Professor Airey and Mr. Oxford, and they claim that the power required per cubic inch of metal per minute will be the same for the same maximum chip thickness for all cutters having similarly shaped teeth irrespective of the number of teeth.

Effect of Number of Teeth in Cutter

Several groups of tests were run in the studies of the effect of varying the number of teeth in the cutter. In the first group the speed and depth of cut were kept constant and the feed varied. This of course varied the chip per tooth and the output in cubic inches per minute and gave the comparison between cutters where equal finish is required for corresponding capacities. The second group contains tests where the feed and depth of cut were kept constant and the cutting speed varied. This gave a constant output and a variable chip per tooth. For the same feed per tooth the best surface finish is secured with the coarsest-tooth cutter. In the third group the depth of cut was kept constant and the cutting speed varied with the feed so as to give a constant chip per tooth. The output of course varied with the speed. This made a good study of the effect of the cutting speed on power requirements.

The tests in the first group are plotted in Figs. 1 to 4, each set

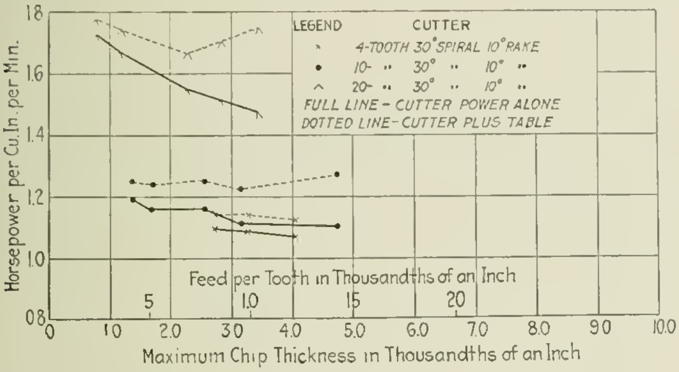

Fig. 5 Power Required by Coarse- and Fine-Tooth Cutters—Constant Feed, Constant Depth of Cut, and Variable Speed

(Material cut, mild steel; width of cut, 5.5 in.; depth of cut, 0 100 in.; feed, 4.1 in. per. min.)

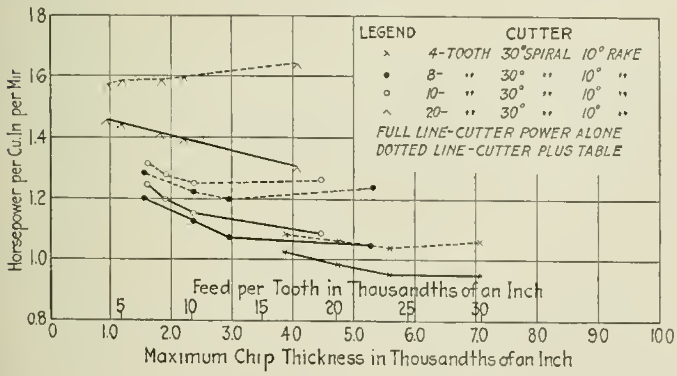

Fig. 6 Power Required by Coarse- and Fine-Tooth Cutters—Constant Feed, Constant Depth of Cut, and Variable Speed

(Material cut, mild steel; width of cut, 5.5 in.; depth of cut, 0.050 in.; feed, 8.20 in. per min.)

of tests being made with a different width or depth of cut. These show that for the same cutting speed the cutter with the smaller number of teeth always takes less power and that this difference is more noticeable on wide cuts. Moreover the fine-tooth cutter gave considerable trouble from chatter on these cuts, especially when the depth was 0.200 in., where it was impossible to use it beyond a limited capacity. This shows that the width of the work is a necessary factor in the determination of the number of teeth in the cutter.

In a number of the tests plotted in Figs. 3 and 4 the fine-tooth cutter was run at approximately half the standard speed to see what effect this had on power consumption. When compared on the basis of cutter power alone, the slower speed showed a saving but not enough to bring it down to the coarse-tooth cutter. When the table power was added to the cutter power as was done in several tests in Fig. 4, the relative advantage of the slower cutting speed practically disappeared.

The real criterion of the effect of chip size on power requirements can best be determined from tests where the feed per tooth is variable but the output is constant. The second group of tests was carried on with this point in view and some of the results are plotted in Figs. 5 and 6. These show that the power efficiency is greater with coarser-tooth cutters even when compared on a chip-per-tooth basis and when only the power required by the cutter is

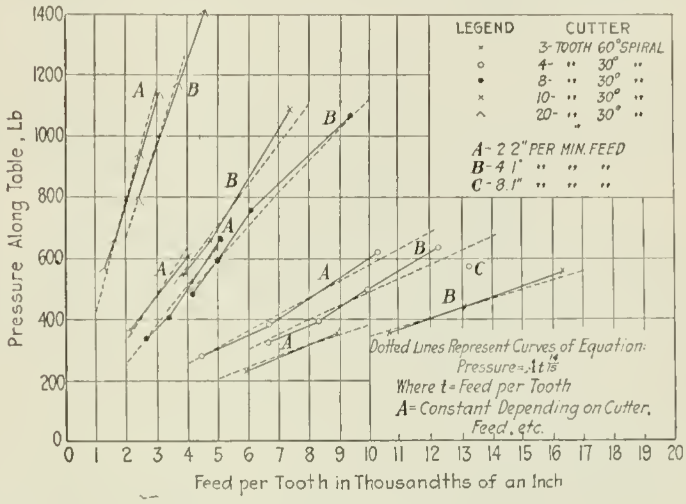

Fig. 7 Effect of Number of Teeth in Cutter on Horizontal Pressure along Milling-Machine Table

(Material cut, mild steel; width of cut, 5.5 in.; depth of cut, 0.050 in.)

considered. When the table power is added to the cutter power, the advantage of the coarse-tooth cutter is even more apparent.

An interesting point about these curves is that the sum of the cutter and table power comes to a minimum as the cutting speed is reduced, after which the table power increases more rapidly than the cutter power is reduced by the increased size of the chips. This point will be referred to again a little later.

Fig. 7 gives the results of a series of tests where the horizontal thrust along the table was measured at several different cutting speeds and two different outputs for each of five cutters. As the depth of cut was small, the power required by the cutter is practically equal to the product of the pressure multiplied by the velocity of the cutter. This checked rather closely with the amount determined from the wattmeter readings where these were taken.

The first point to be noted in this figure is that the pressure increases as the cutting speed is decreased to give a larger feed per tooth. Also if two cutters with different numbers of teeth are operated at the same total feed and also the same feed per tooth, the pressure caused by the cutter with the larger number of teeth is greater by a somewhat larger amount than given by the tooth ratio. The eight-tooth cutter is a little high on this basis, but this is due to the fact it was somewhat duller than the others. Machines and fixtures have limitations in the pressures for which they are designed, and this certainly limits the extent to which it is desirable to go in running fine-tooth cutters at slow speeds to give a large chip per tooth.

Another point of interest is that the curves for higher feeds all fall below those for lower feeds when plotted on a feed-per-tooth basis. The main difference between these tests is that the cutting speed is higher for the larger feeds. This raised a question as to the accuracy of the assumption often made that the cutting speed has no effect on the energy required per cubic inch of metal removed, and a special series of tests were made to study the effect of this variation. The results of these tests are presented a little later in the paper.

The data given in Fig. 7 were plotted on logarithmic cross-section paper and found to form a family of curves of the equation:

$$P = At^{14/15}$$

where P = horizontal pressure along table

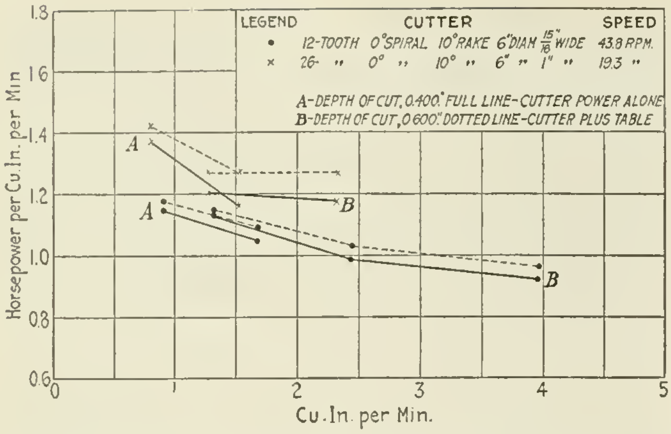

Fig. 8 Power Required by Coarse- and Fine-Tooth Side Milling Cutters Cutting Mild Steel—Constant Speed, Variable Feed

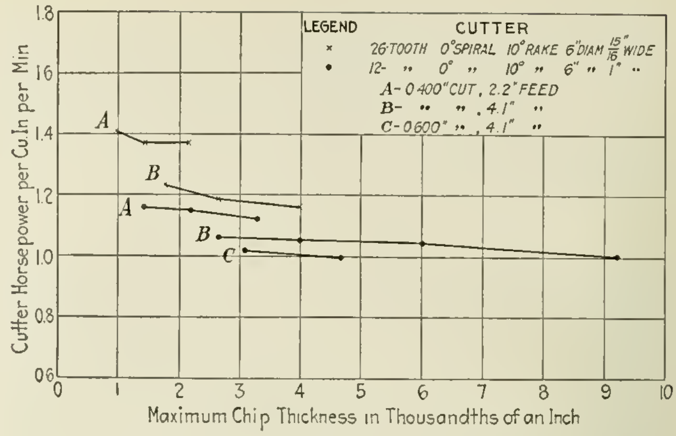

Fig. 9 Power Required by Coarse- and Fine-Tooth Side Milling Cutters Cutting Mild Steel—Constant Speed, Variable Feed

t = feed per tooth, and

A = a constant depending on cutter and feed.

Curves of this equation are plotted in Fig. 7 to show how they conform to the actual results. The number of tests involved is not sufficient to commit the authors absolutely to the power "$^{14}/_{15}$" but they feel sure that the correct figure is only a small amount below unity. In this connection it is interesting to note that the above figure is the one given by Frederick W. Taylor in his Art of Cutting Metals in the results of his experiments with lathe tools cutting mild steel.

Having an equation in the above form, it is possible to calculate for shallow cuts the proper relation of cutting speed and table feed to give the minimum power noted in the discussion of Figs. 5 and 6. Given—

V = cutting velocity in feet per minute

v = table velocity in feet per minute

E = efficiency of the table

$$\text{Horsepower} = \frac{P}{33000}\left(V + \frac{100\,v}{E}\right) \quad \ldots\ldots\ldots\ldots [1]$$

But $P = At^x$ and $t = Bv/V$, where B = a constant depending on the cutter. Substituting these values in [1] and solving for the value of V to make the power a minimum for any given feed and table efficiency,

$$V = \frac{100\,x}{(1-x)E}v \ldots\ldots\ldots\ldots\ldots\ldots [2]$$

For example, if $x = {}^{14}/_{15}$ and E = 14 per cent, $V = 100v$.

Equation [2] gives a limit beyond which there is no saving in power when the cutting speed is lowered to give coarser chips per tooth.

Figs. 8 and 9 give the results of the studies with the side milling cutters. The two cutters were exactly alike except for the number of teeth and a slight variation in width. Fig. 8 shows tests where the cutting speeds were so arranged that the fine-tooth cutter took practically the same chip per tooth as the coarse-tooth on corresponding cuts. When compared on the basis of cutter power alone the coarse-tooth cutter was superior, and this advantage became still more pronounced when the table power was added. In attempting to carry the cut of 4 cu. in. per min. with the fine-tooth cutter the key in the arbor sheared, giving an illustration of the limitations of the machine in applying the chip-per-tooth theory.

Other series of tests with these cutters are shown in Fig. 9, the comparison being on a maximum-chip-thickness basis. Here again the fine-tooth cutter required more power and also proved inferior from the standpoint of chatter, as it was impossible to carry some cuts with it which were taken by the coarse-tooth cutter without a sign of distress.

Frequently in comparing results on a feed-per-tooth or a maximum-chip-thickness basis the power required per cubic inch per minute and the pressures along the table have been less for higher cutting speeds. The tests shown in Fig. 10 were therefore run to check up this relation. A set of cutting speeds and table feeds were arranged so as to keep the chip per tooth nearly constant as the cutting speed was increased. The power delivered to the cutter was taken from the wattmeter readings and checked by the horizontal-pressure figures. The results show that the horizontal pressure and the power required per cubic inch of metal per minute decreased as the cutting speed increased. The vertical pressure between cutter and work remained constant. In other words, if we compare removing 5 cu. in. per min. at 150 ft. per min. cutting speed with removing 1 cu. in. at 30 ft. per min. from the same place with the same cutter, the pressure tending to tear the piece from the fixture and the horsepower required per cubic inch will both be less in the first case. The explanation of this may be that the friction between cutter and work plays a much more important part in milling than in lathe work and that the coefficient of friction decreases as the speed increases.

It would doubtless seem from the foregoing that the efficiency of

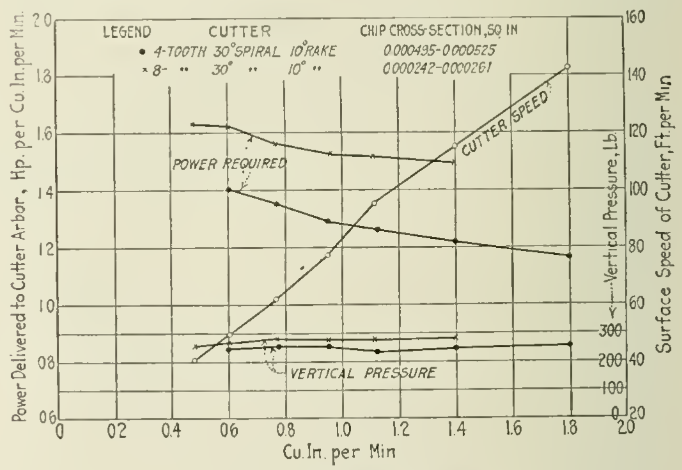

Fig. 10 Power and Vertical Pressure—Constant Chip per Tooth and Variable Load

(Material cut, mild steel; width of cut, 5.5 in.; depth of cut, 0.050 in.)

milling is increased by greater feeds per tooth. If these heavier chips are secured by using lower cutting speeds, the loss in the table becomes greater, the cutter itself requires more power per unit of metal than would be required for the same chip at higher speed, and the pressures between cutter and work become greater. The answer from the standpoint of power efficiency alone is then to use the cutter with the fewest possible teeth and to run it at higher speeds where the size of the chip is too great. The limitations to this practice are the danger of hammer or shock due to lack of continuity of cutting and the possibility of overheating the edges of the teeth due to the heavy pressures and high speeds. The structural strength of the tooth itself is not a limitation in well-designed cutters as this is practically always greater than the strength of the key or the arbor. The relation between the overheating of the edges of the teeth and the number of teeth in the cutter can only be settled by judgment, as no work has been done on the relative effect of cutting speed, volume and length of chip, ductility of the

(Continued on page 205)

The Elasticity of Pipe Bends

By Sabin Crocker[1] and S. S. Sanford,[2] Detroit, Mich.

In this paper the authors develop in detail mathematical formulas connecting the deflection of different types of pipe bends with the force producing deflection, and also expressing the stress set up as a function of the observed deflection and the constants of the bend. They describe experiments made to check force vs. displacement, and present charts for use in selecting the proper size and shape of bends to take care of a given expansion, and to determine the force exerted by a bend when in a given state of deflection. In general they recommend bends of larger dimensions than are ordinarily used, and their figures are said to be on the side of safety. In some cases the bends tested showed a greater flexibility than anticipated, due to minute folds formed on the compression side when bending pipe to short radius.

The use of expansion loops, offsets in the line, right-angled turns and similar devices to furnish flexibility for expansion and contraction in pipe lines resulting from temperature changes, has been general practice for years. Such bends, which utilize the elasticity of the pipe itself, are very commonly used for high-pressure work in preference to slip joints, corrugated expansion joints, or swivel offsets in which screwed elbows are arranged to turn on pipe threads. The use of pipe bends reduces internal friction in the piping by providing easy turns, eliminates unnecessary fittings and joints, and facilitates clearing other pipes and structural interferences.

Up to the present time the disposal of expansion and contraction in power-plant piping has been largely a matter of judgment rather than of rational calculation on the part of the designer. This has been due to a general lack of knowledge or interest regarding the principles and methods involved in calculating the forces and stresses resulting from the expansion of piping. However, if certain rather fundamental principles of engineering mechanics are brought into play, it is usually possible to determine numerical values with fair accuracy during the progress of design, and make use of this knowledge to improve the piping layout. As the drift toward higher steam pressures and temperatures in turbine practice continues, the problem becomes more and more important. Since there is also a tendency for the steam turbine to grow smaller relative to the size of the steam line to which it is connected, there is a danger that excessive stresses will be set up in the turbine casing as a result of expansion in the pipe line unless the piping designer knows how to calculate the forces involved.

The amount of expansion to be cared for in a pipe line can be accurately computed, provided the temperature range between extreme hot and cold conditions, the length of pipe, and the coefficient of expansion for the material are known. Having computed the amount of expansion or elongation of the pipe, the problem resolves itself into determining whether the piping arrangement under consideration has sufficient "spring" to absorb this elongation without producing either undue fiber stress in the material or excessive forces tending to tear the piping loose from its anchors. At the same time the proportions of the line must be economical and be adjusted to clear any structural interferences in the plant. Wall thickness and diameter of pipe, radius of curvature, and general layout all affect the flexibility which can be obtained with a given run of pipe.

The inadequacy of the usual methods of steam-pipe design has been brought forcibly to the attention of The Detroit Edison Company by several minor mishaps during the past few years. Fortunately, none of these were of a serious nature, but they did serve to show that piping laid out according to the best modern practice may be subject to forces of unexpected proportions. Thus in one instance unexpectedly large reactions caused a 14-in. high-pressure steam main to tear loose from what was supposed to be an adequate anchorage. This incident, and others of a somewhat similar nature, led those responsible for design and operation to ask themselves whether such failures could not be avoided by more intelligent design. Consequently, in undertaking the design of the company's Marysville power plant, where the elongation per hundred feet of steam pipe amounts to almost seven inches and the steam pressure is 300 lb. per sq. in., it was decided that pipe expansion must be cared for in a rational manner if such a thing were possible. Accordingly, the investigation here reported was undertaken to determine the fundamental relations between deflection, force resisting deflection, and stress set up in expansion pipe bends of various shapes. These relations were first determined mathematically, and later checked by physically testing bends of shapes which readily lent themselves to measurement of the quantities involved. The results thus obtained were then applied to the more complicated conditions in actual pipe lines. As a result it was possible to design the piping layout for the first section of the Marysville power plant, which has just been put in operation, so that the following results are obtained without allowance for cold springing:

Maximum fiber stress in pipe wall..... 6900 lb. per sq. in.
Maximum thrust against pipe anchorage 680 lb.
Maximum thrust against turbine flange 580 lb.

If credit is taken for cold springing, the maximum stress and forces given above are further reduced. These values have been obtained without making the expansion bends unnecessarily large.

Previous Work by Others

Before proceeding along independent lines an extensive search was made for existing literature, which disclosed that very little had been written on the subject. However, the following articles are of special interest:

(*A*) Formoenderung und Beanspruchung federnder Ausgleichroehren Strains and Stresses in Expansion Bends), by Prof. A. Bantlin, *Zeitschrift des Vereines deutscher Ingenieure*, Jan. 8, 1910, p. 43.

(*B*) Expansion of Pipes, by Ralph C. Taggart, *Trans.Am.Soc.C.E.*, paper No. 1167, Dec., 1910.

(*C*) Elasticity and Endurance of Steam Pipes, by C. E. Stromeyer, *Engineering*, June 19, 1914, p. 857 (from a paper read before the Institution of Naval Architects).

(*D*) Pipe Bends, Their Growing Use and Efficacy, *The Valve World*, Oct., 1915 (published by Crane Co.).

(*E*) The Design of Pipe Bends for Expansion in Pipe Lines, by J. G. Stewart, *Power*, May 10, 1921, p. 742.

Reference (*A*) deals with the comparison of physical tests and calculated results for bends similar to our double-offset expansion U-bends.

Reference (*B*) treats principally of the use of straight pipe and fittings in making up expansion loops. The results are in general similar to those of the present authors for straight lengths of pipe.

Reference (*C*) describes a series of failures of steam pipes in service, due to repeated strains beyond the elastic limit. A set of formulas similar to those presented in this paper was worked out to show what elongations could be cared for without eventually producing failure.

Reference (*D*) is a report of physical tests on pipe bends made by the Mechanical Experts Department of Crane Company, and published in their organization paper, *The Valve World*. A series of curves deduced from their experimental data and giving the amount of expansion required to produce a fiber stress of 15,000 lb. per sq. in. in different-shaped bends was included for the use of those interested in pipe design.

Reference (*E*) gives a method of computing fiber stress similar to that of Reference (*C*), and a chart for reading the elongation corresponding to 15,000 lb. per sq. in. stress for different bends.

It is worth comment that while the author's formulas were worked out independently of Reference (*C*) and before Reference (*E*) was published, all three sets are practically identical. The comparison of theoretical formulas with actual test results, and the rather complete design graphs worked out in this paper, take the subject a step beyond the point reached by earlier publications. The fact that none of the previous investigators has published all of the mathematical steps leading up to his final formulas, will make the derivations given in the complete paper by the authors of special interest to any one having occasion to work with the formulas.

[1] Piping Engineer, Detroit Edison Co., Assoc-Mem. Am.Soc.M.E.
[2] Research Department, Detroit Edison Co., Jun.Am.Soc.M.E.

Contributed by the Power Division and presented at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. Abridged. All papers are subject to revision.

Table 1 is a summary of such data published in the above references as were in shape to reduce to a common form for comparison with the work of the present authors. It will be noted that the formulas of References (*C*) and (*E*) agree very closely with those of this paper, while Reference (*D*), which has been widely quoted during the past seven years, differs considerably from the others except for the double-offset expansion U-bend. The following extract is quoted from Reference (*D*):

> A 180-deg. or U-bend has twice the expansive value of a 90-deg. or quarter-bend of the same size and radius, and an expansion U-bend, four times the expansive value of a quarter-bend or twice that of a U-bend. A double-offset expansion U-bend has five times the expansive value of a quarter-bend, two and one-half times that of a U-bend, and one and one-fourth times that of an expansion U-bend.

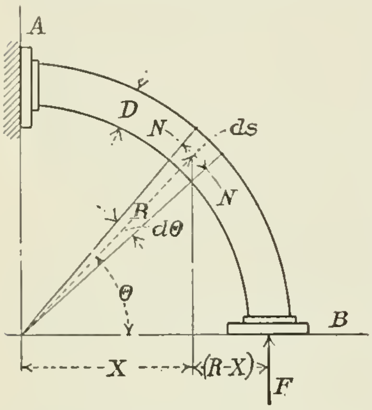

Fig. 1 Quarter-Bend, Force Axial

In other words, the relative ability of these particular bends to take up expansion without exceeding a safe stress is stated by Reference (*D*) to be in the ratio of 1 : 2 : 4 : 5, while the calculated ratio given by References (*C*) and (*E*), and checked by the present authors, is 1 : 4.4 : 13.2 : 32.9, assuming that the quarter-bend is connected to the pipe line so that the thrust of the line acts along the axis of the pipe in the bend at the joint, as shown in Fig. 1.

Referring to the stress index of Table 1, Reference (*D*) agrees quite closely with the others' results for double-offset expansion U-bends, but gives much higher values for the expansion cared for by quarter-bends, U-bends, and expansion U-bends than do the others. It will also be noted that the stress and flexibility indexes for the double-offset expansion U-bend given by reference (*E*) differ slightly from those given by the present authors. This is because the two bends considered are not of exactly the same shape.

A peculiarity of bends noted in Reference (*A*) was also observed in some of the bends tested by the authors, i.e., that the elasticity found by test exceeded the computed elasticity. Reference (*A*) describes tests on three kinds of bends formed to a shape which resembles a double-offset expansion U-bend, the first variety being bent from solid rod stock, the second from steel pipe, while the third was a hollow iron casting similar to a pipe bend. Tests of the first and third varieties checked very closely with calculated results, while the bend fabricated from a straight length of pipe was found to be much more elastic than the calculations indicated. The explanation given in Reference (*A*) is that the large deflections of the steel pipes must be attributed chiefly to waves or folds upon the compressed side of the pipe.

This conclusion is supported by the results presented here, all of the test bends formed to a radius of five pipe diameters or less having a flexibility in excess of calculated values, while, with one exception, those formed to a radius of six diameters or more gave results agreeing closely with those obtained by the formulas. This would seem to indicate that the excessive elasticity was due to puckers or folds in the pipe wall produced in the process of bending, the tendency being to thin the pipe wall at the outer circumfer-

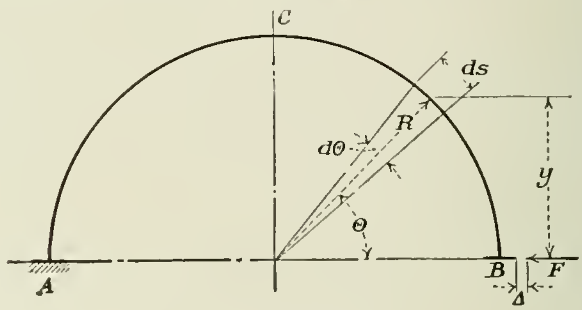

Fig. 2 Plain U-Bend

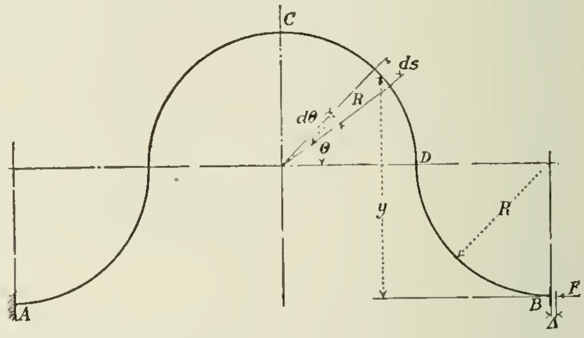

Fig. 3 Expansion U-Bend

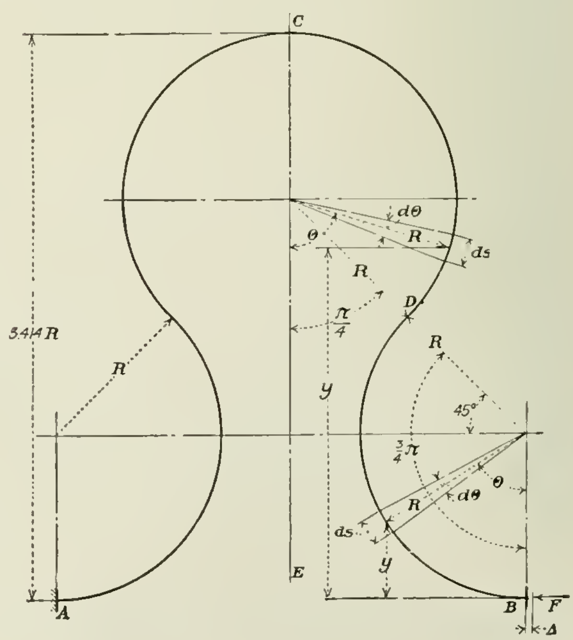

Fig. 4 Double-Offset Expansion U-Bend

TABLE 1 SUMMARY OF DATA ON PIPE BENDS

Reference	C = Stress Index, C, in $S = C\dfrac{D\Delta E}{R^2}$				K = Flexibility Index, K, in $\Delta = K\dfrac{FR^3}{EI}$			
	Quarter bend	U-bend	Expansion U-bend	Double-offset expansion U-bend	Quarter bend	U-bend	Expansion U-bend	Double offset expansion U-bend
(*C*) C. E. Stromeyer[1]	1.404	0.318	0.106	0.0495	0.356	1.571	9.426	34.54
(*D*) Crane Co.[2]	0.2	0.1	0.05	0.04	—	—	—	—
(*E*) J. G. Stewart[1]	1.404	0.318	0.106	0.045	0.356	1.571	9.42	37.9
Crocker & Sanford, Calculated	1.404	0.318	0.106	0.0427	0.356	1.571	9 42	39 88
Crocker & Sanford, Test	—	—	0.048 to 0.106	0.042 to 0.0427	—	—	9.42 to 20 8	39 9 to 40.7

Definitions of Symbols

- C = stress index (numerical values given in left half of table).
- K = flexibility index (numerical values given in right half of table).
- S = maximum bending stress in pipe wall, lb. per sq. in.
- D = outside diameter of pipe, in.
- R = mean radius to which bend is formed, in.
- E = modulus of elasticity (30,000,000 lb. per sq. in. for steel).
- I = moment of inertia of section, taken normal to center line of pipe of which bend is formed, in.[4]
- F = forc causing deflection of bend, lb.
- Δ = deflection of flange of bend = elongation of pipe line due to change in temperature, in = totel expansion to be absorbed by bend, i.e., total expansion calculated for a straight run of pipa with length equal to distance between anchors which occur nearest to bend under conesideration.

[1] For references, see previous paragraphs.
[2] Formulas deduced from curves published in *The Valve World*, Oct., 1915
For shape of bends see Figs. 1, 2, 3, and 4.

ence of the bend and form minute crinkles or waves at the inner circumference. These conditions are more pronounced the shorter the radius of curvature, and in the case of the bend described in Reference (A), which was bent to a radius of only three to four pipe diameters, the waves were plainly visible. In American practice, where the minimum allowable radius of curvature is limited to five or six pipe diameters, these waves are not so visibly evident, nevertheless we may assume that they are present and have the effect of increasing the flexibility of bends formed to too short a radius.

Formulas and Design Graphs

A pipe bend may be considered as a beam of special form, one end of which is fixed and the other end of which is free to move in the direction of a force acting upon it. Since the bend is an elastic body, the movement of its free end will be proportional to the force acting, within the elastic limit of the material.

In the complete paper expressions are derived for the deflection Δ and the maximum bending stress S for the quarter-bend (Fig. 1), the U-bend (Fig. 2), the expansion U-bend (Fig. 3), and the double-offset expansion U-bend (Fig. 4), which are given in Table 1.

In each case, flange A has been considered as fixed. Such a condition would exist if the line to which A is connected where anchored at that point, or if A were a flange at the turbine. As a matter of fact, the entire analysis is really based on the movement of flange B with respect to A, and it makes no difference whether A is actually fixed or is permitted to move. F is the net force with which the pipe line pushes against the flange B when the line is hot. For design purposes the total expansion to be cared for between anchorages is determined from known or assumed temperatures, length of pipe, and coefficient of linear expansion. The length of pipe used is a nominal length equal to the actual linear distance between anchorages. In effect, it is as though a line of pipe such as that shown in Fig. 5 were assumed to be like that in Fig. 6, with the total movement due to the expansion of a straight pipe of length L applied at the flange B.

For the convenience of the power-plant designer, the formulas for several of the standard bends are represented graphically in Figs. 7, 8, and 9. The bends considered are the quarter-bend, U-bend, expansion U-bend, and the double-offset expansion U-bend with the forces applied as shown in the small figures on the graph and corresponding to Figs. 1, 2, 3, and 4. The forces and stresses set up in bends made up of pipe sizes up to and including 20 in., and bent to radii up to and including 120 in., may be read from these graphs without the necessity of solving the formulas.

Fig. 7 gives the maximum bending stress in the pipe wall of the bend for any expansion in the pipe line which must be cared for. Inasmuch as the stress is proportional to the outside diameter of the pipe for any given value of Δ, and is independent of its weight, this diagram serves for all weights of pipe. This diagram is drawn up for 8-in. pipe and values for that size may be read directly. For instance, an 8-in. expansion U-bend, formed to a radius of 60 in. and required to take up an expansion of 0.7 in. in the pipe line, would have a maximum bending stress set up in it of 5380 lb. per sq. in.

A sample problem will indicate the method to be used for other sizes of pipe. Since the stress is proportional to the diameter of the pipe, the value of the stress for any size of pipe may be obtained after finding the stress in an 8-in. pipe. The proportion between stresses can be made directly on the diagram by following the radial lines diverging from its lower right corner.

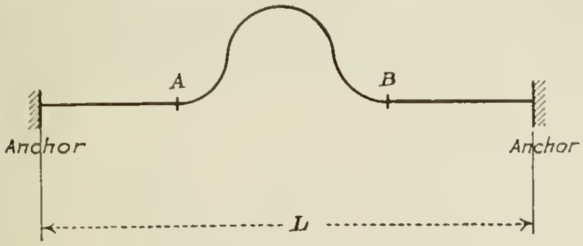

Fig. 5 Actual Piping Layout

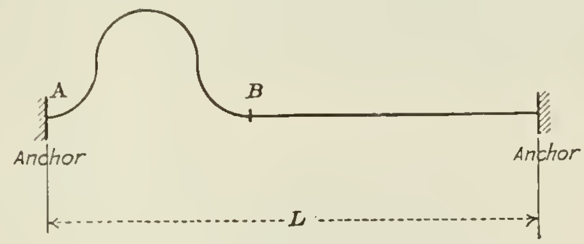

Fig. 6 Layout as Assumed for Calculation

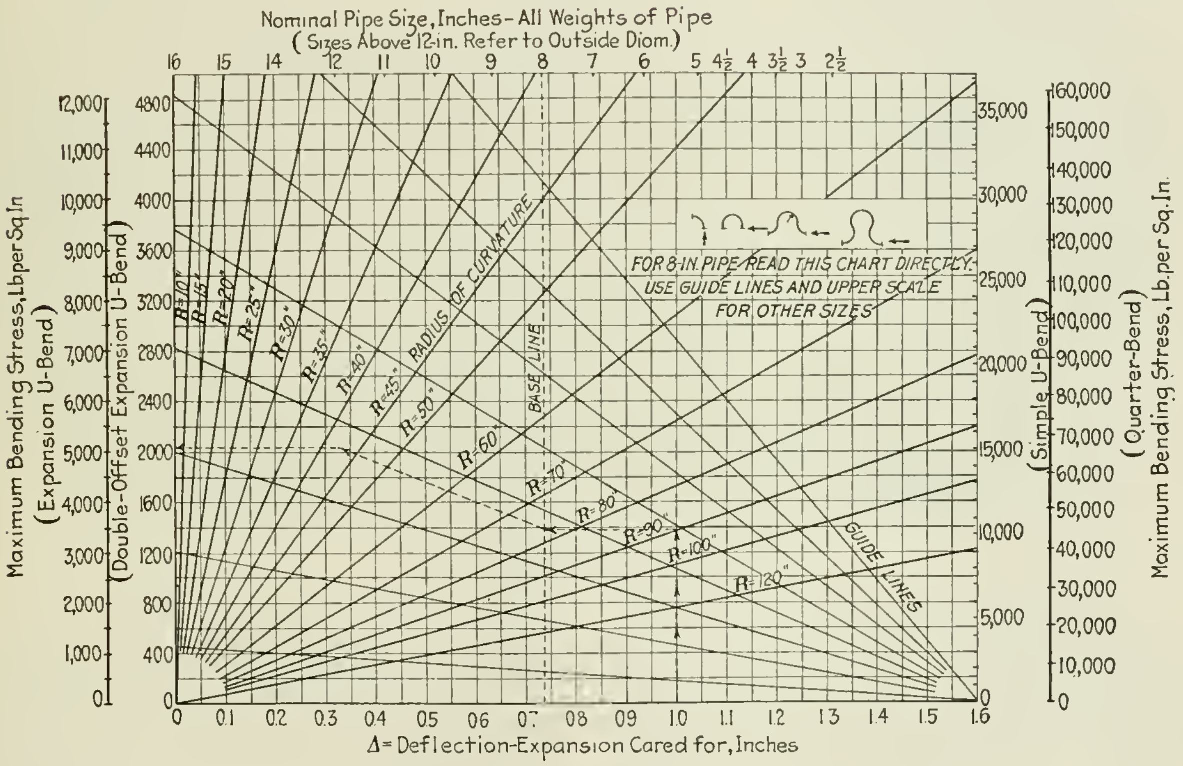

Fig. 7 Stress vs. Displacement for Various Shapes and Sizes of Pipe Bends

Sample Problem: A 12-in. double-offset expansion U-bend having a radius of 90 in. is to take up an expansion of 1 in. Required, the maximum bending stress in the bend.

From the intersection of $\Delta = 1$ in. and $R = 90$ in., extend horizontally to the vertical line under 8-in. pipe, which is referred to as the "base line," and the obliquely (with a line passing through lower right-hand corner) until under 12-in. pipe on the upper scale. The result is 2040 lb. per sq. in.

Since the stress is directly proportional to the displacement, this diagram may be used for values of Δ which fall beyond its range by multiplying both stress and displacement scales by the same factor. For instance, if a 5-in. expansion is to be considered, the stress for an expansion of 1 in. should be read on the graph and multiplied by 5.

Figs. 8 and 9 give the forces set up in the pipe line when pipe bends are used to take up the expansion. As these relations are functions of the moments of inertia of the pipe sections the internal diameters affect the results, and Fig. 8 has been drawn for "standard weight" and Fig. 9 for "extra heavy" pipe. These diagrams are for 16-in. pipe and values for this size may be read directly. The scale of pipe sizes at the top of diagram is laid off according to the moment of inertia of the pipe section, as the force to produce a given base line under 16-in. pipe, for making the proportion. The solution for a sample problem is indicated by the dash lines in Fig. 8. A double-offset expansion U-bend made of 14-in. O.D. pipe, $^3/_8$ in. thick, formed to a radius of 80 in., is required to take up the expansion of 1.1 in. in the pipe line. From the diagram, the force acting against the pipe anchorage is 610 lb.

Since the force is directly proportional to the displacement, these diagrams also may be used for values which fall beyond their range by considering both force and displacement scales as multiplied by the same factor. It should be noted that in using these diagrams the pipe size refers to the size of pipe used in the bend and has nothing to do with the size of pipe in the rest of the line.

Results of Tests

In all, eight separate expansion bends were tested. The methods employed in testing are described in the complete paper. The results are given in condensed form in Table 2.

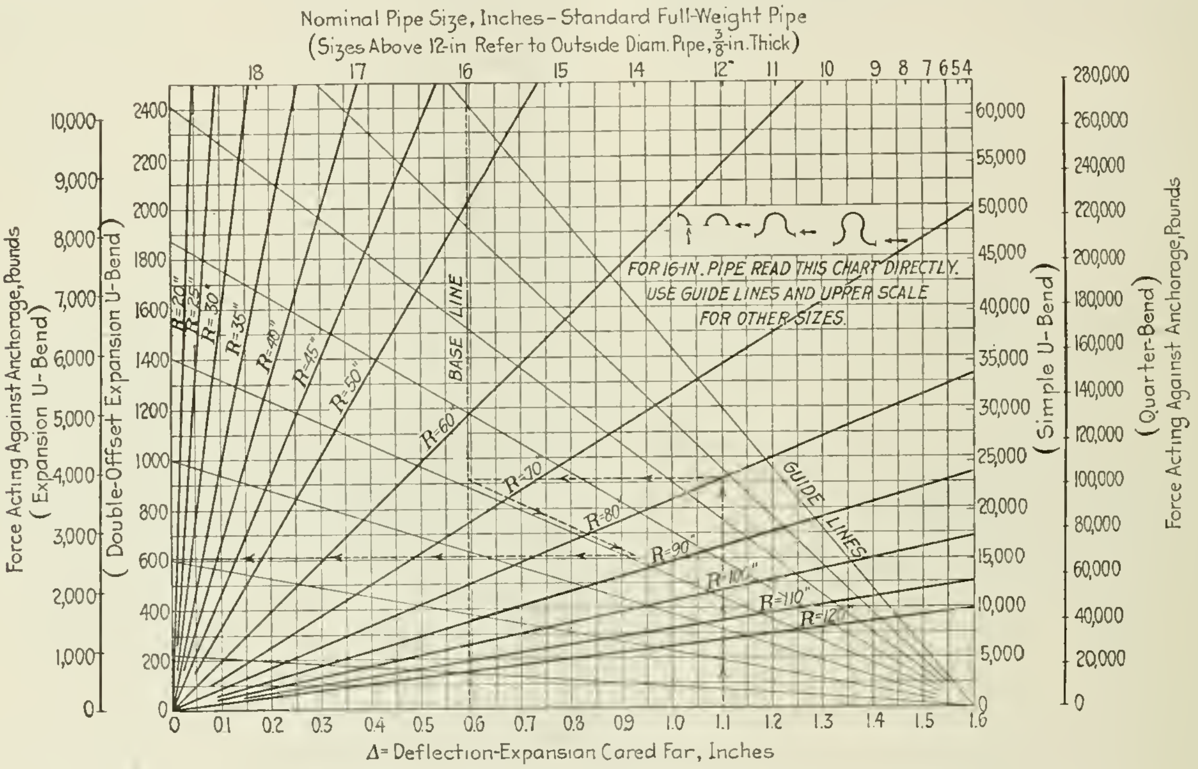

Fig. 8 Displacement vs. Force Exerted or Various Shapes and Sizes of Pipe Bends—Standard Pipe

deflection in the bend is proportional not to the diameter, but to the moment of inertia of the pipe.

After finding the force existing for a given deflection in the 16-in. pipe, the value for any other size of pipe may be obtained by using the radial lines diverging from the lower right corner, and the vertical

TABLE 2 RESULTS OF TESTS BY AUTHORS ON EXPANSION BENDS

Type of U-Bend	Nominal size of pipe, in.	Measured thickness of pipe, in	Radius of bend, in terms of nominal pipe diameter D	Flexibility index[1] K Calculated	Flexibility index[1] K Observed
Expansion U-bend	10	0.336	$6D$	9.42	29.8
Expansion U-bend	6	0.418	$6D$	9.42	9.42
Expansion U-bend	6	0.27	$5D$	9.42	14.08
Expansion U-bend	6	0.274	$5D$	9.42	16.88
Expansion U-bend	6	0.285	$5D$	9.42	12.02
Double-offset exp. U-bend	6	0.41	$6D$	39.88	39.9
Double-offset exp. U-bend	4	0.237	$7D$	39.88	40.7
Expansion U-bend	3-1/4-in. boiler tube	0.12	$8.31D$	9.42	9.42

[1] In formulas in Table 1

As noted before, the results from bends formed to a radius greater than 5 pipe diameters agree closely with those obtained from the formulas with one exception, this exception being the 10-in. expansion U-bend. The radius in this case was 6 diameters. The pipe in this bend was the largest size tested, all others being 6-in. or smaller. It is relatively more difficult to bend large pipe than small pipe, so as the pipe size increases the minimum allowable radius (expressed in pipe diameters) also has to be increased. One American manufacturer states that the shortest radius to which a 22-in. standard pipe can be bent is 6 diameters, while a 5-in. pipe can be bent to 4 diameters. In other words, there is relatively greater danger of the pipe buckling or having waves and folds in it in the larger sizes. It is entirely possible that these are responsible for the unexpected flexibility in this 10-in. bend. The bend was too large to be made from one length of pipe, so it was welded at the top of the loop. The bend was one purchased especially for test and had not seen service.

The first 6-in. expansion U-bend in Table 2 was one purchased especially for test and had not previously seen service. In this case there is a very satisfactory agreement between test and formula.

The remaining three 6-in. expansion U-bends were bought for the auxiliary superheated-steam line at the

Connors Creek power house and had not seen service at the time of the test. All were formed to a radius of 5 diameters and all had a flexibility in excess of the calculated value.

The two double-offset expansion U-bends were purchased especially for test and had a flexibility agreeing closely with the calculated values.

In order to eliminate as much as possible the formation of waves or folds in the pipe during the bending operation, a $3^1/_4$-in. expansion U-bend was made up from a straight boiler tube in a Babcock and Wilcox boiler-tube-bending machine. In this machine one end of the tube is clamped to one end of a quadrant having a grooved face and a radius of 27 in. This quadrant turns on its axis and is geared to a motor, the tube sliding against a stationary grooved wheel on the machine as the quadrant is turned. The length of the tangent from the grooved wheel to the circumference of the quadrant is relatively short. A second grooved wheel on the end of a lever which is pivoted near the axis of the quadrant assists in the bending. In this way compression on the inner side of the bend is minimized, reducing the danger of having waves or folds formed in the tube. The bend was formed cold in this machine, as nearly as possible to shape, and then removed and heated where necessary, and the bending operation completed. The test results show a very close agreement with calculated values. It should be noted that the radius of the bend with respect to the diameter of the pipe is greater than with any of the other bends tested. This tends to bear out the theory that those bends which are more flexible than the formula would indicate, owe their extra flexibility to waves formed on the compression side of the bend when a pipe is bent to a short radius.

Attention is called to the fact that in no case did the tests show a bend to be less flexible than the formulas would indicate, so if the formulas and the design graphs presented in this paper are used in practice, the designer will always be on the safe side. His bends may or may not be more flexible than his calculations would indicate, depending upon how the bends were made, but he need not fear that forces or stresses in excess of his calculated values will exist.

All the bends were tested while cold. Since the physical properties of mild steel are not altered appreciably up to 700 or 750 deg. fahr., which are about the maximum temperatures to be expected in a steam line with present practice, the relation between force and deflection should be the same whether the pipe is hot or cold.

The test method used was a rather crude one, yet in several cases the agreement between calculated and test values is remarkably close. It will be noted that in some cases there is a tendency for the force to become disproportionately larger as the displacement increases. This was doubtless due to the binding of the jack as the flange tended to swing to one side, and the flanges to assume positions at an angle to the pipe line. It should also be noted that in deriving the formulas no allowance was made for a change in shape of the bends as they take up expansion. Actually, the height of the bend, and therefore its flexibility, increases as the bend is deformed, so that for large deflections the actual force will be less than the calculated force. However, as the deflections are relatively small in actual practice, this will not affect the results seriously.

In checking a piping layout to determine if excessive fiber stresses exist anywhere in the pipe wall, the longitudinal bursting stress due to the pressure of the steam should be added to the bending stress given by the formulas. This is especially important when working with high steam pressures.

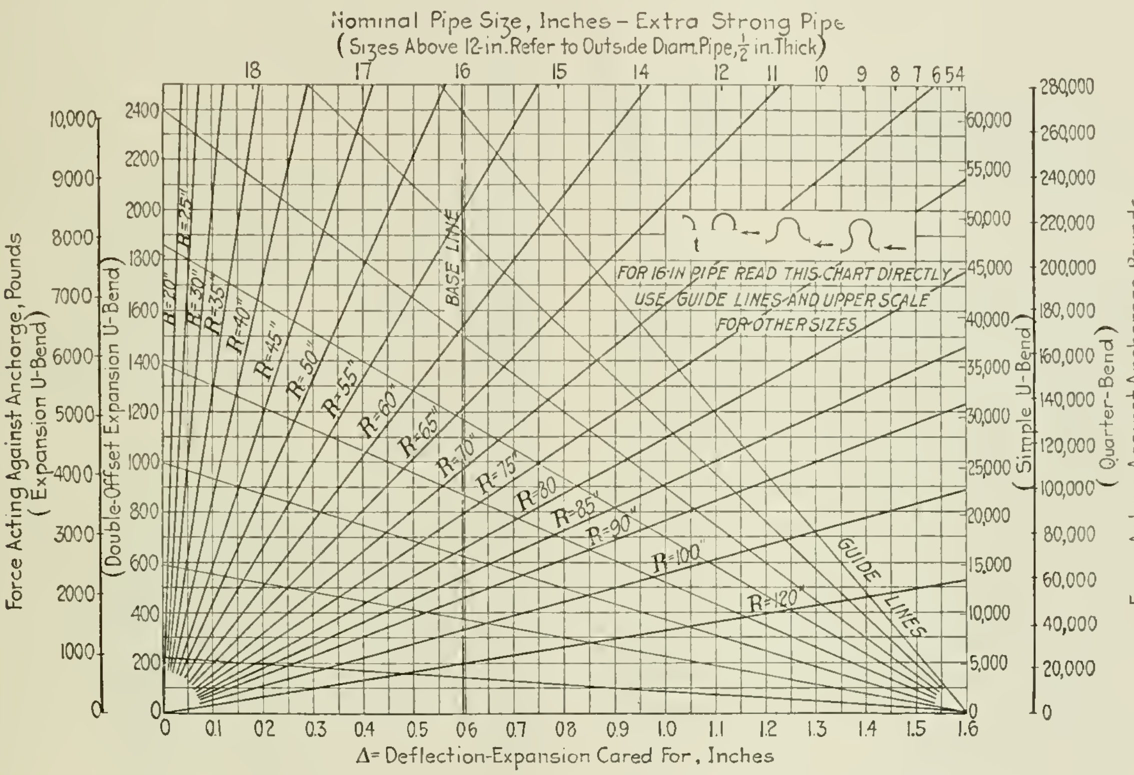

Fig. 9 Displacement vs. Force Exerted on Various Shapes and Sizes of Pipe Bends

Nothing has been said about the expansion which can be compressed back into the pipe by the forces set up at the anchorages. In each case it has been assumed that the expansion bend takes care of all of the expansion and that none of it is compressed back into the straight pipe. Actually, of course, a small part of the expansion is taken up by compression, the amount being directly proportional to the length of the pipe and to the force set up, and inversely proportional to the cross-sectional area of the metal in the pipe and to the modulus of elasticity for that metal. In the case of expansion U-bends and double-offset expansion U-bends, which are very flexible, the amount of expansion compressed back into the pipe is so small compared to the amount taken up by the bend that it can be neglected altogether. In the case of U-bends and quarter-bends, however, the forces are larger and consequently more of the expansion is taken up by compression. In actual practice the amount taken up by compression may be neglected, for in doing so the designer is making a small allowance on the side of safety.

Summary

To summarize in closing: This paper treats of expansion bends in pipe lines as if they were beams acted on by the forces set up by expansion of the piping. Upon this basis formulas have been derived for the forces and stresses in some of the more common types of bends. In the light of the material presented in this paper the

limits of safe expansion values for pipe bends set by Reference (*D*), and commonly quoted in engineering texts and handbooks, are apparently correct only for the double-offset expansion U-bend. For the other shapes the published values are much in excess of those given here. It is the authors' contention that these limits should be revised to agree with the formulas presented in this paper, for unless the published tables are used with large factors of safety, the forces and stresses existing in pipe lines will be excessive and dangerous.

Discussion

The discussion was opened by the reading of a contribution from William B. Campbell[1] who wrote that the right-hand half of the authors' Table 1 gave data for direct comparison of the calculated relations between force F acting on the bend and the deflection Δ produced, and the same relation from actual test. It would appear, however, that the left-hand portion was semi-experimental, in that the calculated values showed a relation deduced analytically between the observed deflection Δ and the maximum fiber stress S was manifestly not observed directly, but was inferred from the experimental value of F which accompanies a given Δ. This method of course reflected the observed relation between deflection and force acting, but it did not eliminate the effect of the method used for calculating S from F, which was based on ideal conditions in the shape and physical dimensions of the pipe. For this reason the "experimental" data in this section were not so conclusive as those in the right-hand section.

Robert Cramer[2] said that it was gratifying to learn that the authors had made an attempt to compare directly theoretical and experimental results. He noted in the paper, however, a point of theoretical nature which should be considered when test results were incorporated. In the diagram giving the basis of the theoretical investigation, the neutral axis of the cross-section of the bend was assumed to pass through the center of the circle, which was not true in the case of a pipe bend. It was a well-known fact, he said, that the neutral axis in curved beams did not pass through the center of gravity of the cross-section as it did in straight beams, and the peculiarity was more pronounced the shorter the radius of the beam compared with the magnitude of the cross-section.

For this reason, he said, it would pay the authors to pursue a line of more rigid theoretical investigation of the deviation of the experimental results from the theoretical results in the case of the shorter bends. He had noted in making comparison between the experimental and calculated results that in some cases the two checked closely, while in others the variation was very marked. It was not the slight variation to be expected from experimental or observational errors, but one which would suggest that the authors should look for some error in their calculations.

The authors considered the deflecting force always to be at right angles to the flange on which it was applied, with the exception of the case of the quarter-bend, in which they had distinguished between two cases, one with the force acting at right angles to the flange and the other with a force acting in the plane of the flange. In the actual case, he said, the problem was really more complicated than would appear from the authors' investigation, as it was frequently necessary to twist the flange in order to make a tight joint, and this involved another source of strain.

Francis Hodgkinson[3] said that the paper was extremely valuable because more and more attention must be given to the very important subject of the flexibility of the steam line. This was the first time, he thought, that reliable information had been presented. Generally speaking, he said, flexibility could be secured by laying out straight runs of pipe at right angles to each other. There was another kind of flexibility which the paper did not mention, and which was torsional flexibility of the pipe. With the decrease in size of turbines and the increase in capacity, the structure of the pipe line was becoming almost as strong as the structure of the turbine itself and it was necessary for the flange to have some angular freedom and that the pipe be arranged in such a way that its whole length would not have to be lifted up because of lack of alignment. It was frequently necessary, he said, to have some length of pipe with torsional flexibility.

[1] Rutgers College, New Brunswick, N. J. Assoc-Mem. Am.Soc.M.E.
[2] Cons. Engr., Milwaukee, Wis. Mem. Am.Soc.M.E.
[3] Chief Engr., Westinghouse Elec. & Mfg. Co., S. Philadelphia, Pa. Mem. Am.Soc.M.E.

J. A. Freiday,[1] speaking as a representative of Thomas E. Murray Inc., said that they considered the paper a valuable contribution, bearing as it did upon a subject which had not always been given proper consideration in the past. The subject was one which they had carefully considered in the numerous power stations they had designed. Up to two or three years ago they had made use of expansion loops made of pipe bends similar to those described in the paper. In a few cases, he said, they had experienced trouble with bends which evidently had not been properly annealed and which showed a tendency to straighten out and grow after being placed in service. In one case the growth of a 14-in. 90-deg. bend exceeded 2 in. in a few months, the increase being measured after the pipe had been taken out of the line.

In order to eliminate the possibility of such distortion and also to take care of the increasing steam temperatures in larger steam lines required by larger modern units, they had made an investigation some time ago to determine the best method of providing for expansion with the least reaction at the point of anchorage. The result of the investigation, he said, had shown that loops corresponding to the expansion U-bends but made up of straight pipe and fittings produced less reaction than an expansion U-bend requiring the same space.

This method of taking care of bends, he said, lent itself particularly to large pipe, for the use of large expansion U-bends was not practical due to fabrication difficulties. With the design of loop they had used in all recent installations no excessive pressure drop had been encountered due to this method of making bends.

He asked the authors if they had investigated any loops designed as he had described.

H. Leroy Whitney[2] said he had noticed many examples of square-bends and U-bends which did not take up the expansion they had been figured for and also, particularly in long transmission lines, he had noticed a double expansion U-bend which had taken over twice the expansion figured for it and that over a period of years marked deterioration in the pipe was shown. In regard to the buckling of pipe on the inside of the bend, he said that it was perfectly evident that if the pipe did buckle on the inside the fibers on the outside were not stressed nearly as much as if the pipe did not buckle. In large bends of comparatively small thickness it was almost impossible to make the U-bend without buckles on the inside. The buckles did no harm, he thought, they did not retard the flow of steam through the pipe to any appreciable extent but did take up expansion. If the pipe was subject to very high vibrations, he said, it was sometimes customary to pull or push them to the full extent that they would be distorted by expansion, so that when they were hot they would be in their normal state, relieving the thrust on steam apparatus.

George A. Orrok[3] said that he understood all the research had been made with cold pipe without pressure on the inside. He wondered if there was any difference between the action of a pipe bend with two or three hundred pounds pressure on the inside and one which was cold. He said that he thought many pipe bends had been designed so that the metal had been stressed beyond the elastic limit. It was a well-known fact that a pipe should not be stressed to 5500 or 6000 lb. This made it necessary to use heavy pipe if the pipes are large. Many times a pipe would rupture at bends when the weld had been placed in the neutral axis. He thought very heavy pipe should not be placed in bends and suggested the use of seamless tubing which was a common practice in our Navy and in the new stations of England and the continent. Such tubing could be stressed up to 12,000 lb.

John A. Stevens[4] asked what would be the thrust from pipe lines with a temperature of about 750 deg., at which the pipe itself would be red hot, and whether there would be a sufficient amount of deformation in the pipe line and the fittings so that the actual thrust would be smaller.

[1] Mech. Engr., Thos. E. Murray, Inc., New York, N. Y. Mem. Am.Soc.M.E.
[2] Director and Sales Engr., The M. W. Kellogg Co., New York, N. Y. Mem. Am.Soc.M.E.
[3] Cons. Engr., New York, N. Y. Mem. Am.Soc.M.E.
[4] Cons. Engr., Lowell, Mass. Mem. Am.Soc.M.E.

Progress in Steam Research

Harvard Investigation in Joule-Thomson Effect Shows First Results—Work Well Started at Massachusetts Institute of Technology and U. S. Bureau of Standards—A.S.M.E. Annual Meeting Session Devoted to Reports and Comments on Progress

On June 23, 1921 a group of scientists and engineers met in Cambridge, Mass., and discussed the available information regarding the properties of steam. As a result of this conference a project of research was planned; the A.S.M.E. was requested to sponsor the program, and the raising of funds commenced under a sub-committee of its Research Committee.

As originally planned, the Harvard Engineering School was to investigate the Joule-Thomson cooling effect in superheated steam at pressures up to 600 lb. and at temperatures up to 600 deg. fahr. The Massachusetts Institute of Technology was requested to determine, under the direction of Prof. Frederick G. Keyes, the pressure-temperature-volume relation of superheated steam at high pressures and over as wide a range of superheats as possible. The United States Bureau of Standards was asked to determine the specific heat of water for a more accurate determination of the mechanical equivalent of the mean heat unit.

At the Annual Meeting session held December 5, 1922, which was presided over by Prof. A. G. Christie, of Johns Hopkins University, reports were received from those in charge of the three investigations. Geo. A. Orrok, Chairman of the Executive Committee of the Steam Table Fund, presented a brief report of the finances. He was followed by Dr. R. V. Kleinschmidt, Research Fellow of Harvard University, and investigator of the Joule-Thomson effect under the supervision of Dr. Harvey N. Davis, who described the apparatus and methods and gave values for Joule-Thomson coefficients up to the pressures at which experiments had been conducted. The work to be carried on at Massachusetts Institute of Technology under the direction of Dr. Frederick G. Keyes was outlined in a paper read by Dr. Davis in the absence of Dr. Keyes, and N. S. Osborne, of the Bureau of Standards, related plans and progress in the work to be carried on at that institution.

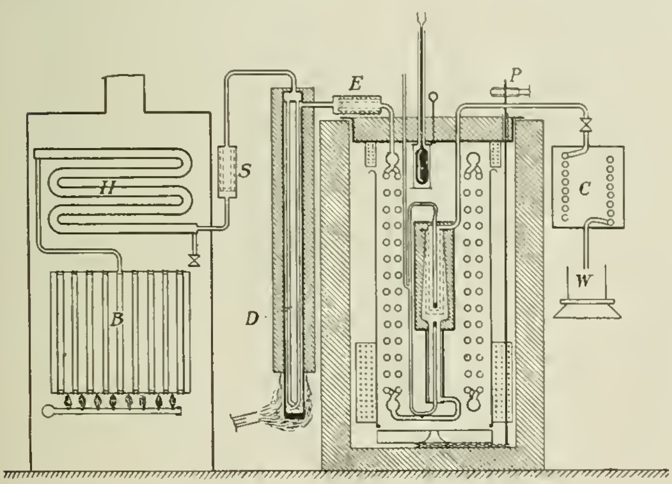

Fig. 1 General Arrangement of Apparatus

The report made by Mr. Orrok, and the remarks of Dr. Kleinschmidt, Dr. Keyes, and Mr. Osborne are given in abstract below.

Report of Executive Committee of Steam Table Fund

Your Committee charged with the raising of the Steam Table Fund has proceeded slowly with its work, the sum total of the subscriptions amounting to approximately $27,000. Of this $8,483 has been paid in and the second payments on the subscriptions are now due.

Your Committee has made two grants of funds and is considering three others in the near future. The first grant was made to Harvard University, to be expended under the direction of Dr. Davis on the investigation of the Joule-Thomson effect. Of this grant $5,333.50 has been expended, leaving a balance of $666.50. The second grant was made to the Massachusetts Institute of Technology, to be expended under the direction of Dr. Keyes on the investigation of the pressure-temperature-volume relations of steam. No money has been expended on this grant as yet.

Your Committee has also been considering a grant to the Bureau of Standards to cover the work which they are preparing to do, and we believe it is now time to finish the raising of the necessary money to carry all of these researches through to the end which we desire.

The Joule-Thomson Effect in Superheated Steam

By R. V. Kleinschmidt,[1] Cambridge, Mass.

Measurements of the Joule-Thomson or "throttling" coefficient, μ, in superheated steam are being made as part of the A.S.M.E. program for standardizing steam tables. Such measurements, supplemented by our present knowledge of specific heats at low pressures, furnish a convenient and accurate means of determining the total heat and the specific volume of superheated steam over any range of temperature and pressure at which the Joule-Thomson observations can be made.

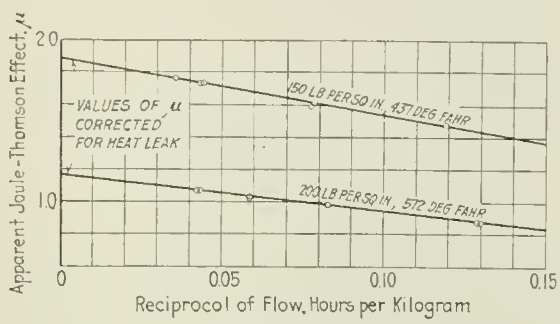

Fig. 2 Trueblood's Method of Correcting for Heat Leak

The experimental procedure consists in forcing steam—carefully dried and brought to the required temperature and pressure—through the walls of a porous tube or "plug" of alundum. The drop in pressure required to force the steam through the pores of the plug is measured on a differential mercury manometer, and the drop in temperature resulting from the throttling is measured by thermocouples read on a potentiometer.

The general arrangement of the apparatus is shown in Fig. 1. Steam is generated in a small gas-fired automobile boiler B, the pressure in which is closely regulated by an automatic control on the gas supply. It then passes through the first (gas-fired) superheater H, which acts also as a water separator. The steam then passed through a porous alundum strainer S, into a counter-current "drier" D, at the bottom of which it is heated far above the temperature at which measurements are to be made, to insure the evaporation of all drops of moisture. In passing up through the drier it is again cooled nearly to the temperature of the steam entering the drier, and it then passes through a second porous-plug strainer E, on which is wound an electric heating coil, by means of which the temperature of the steam can be very closely regulated. The steam then enters the main portion of the apparatus. This is immersed in a cylindrical tank 42 in. deep and 20 in. in diameter, heavily lagged and filled with heavy oil having the highest obtainable flash point. This oil bath is heated by electric heating coils, the current through one of them being controlled by a mercury-bulb thermostat which holds the temperature within $^1/_{100}$th of a degree or closer. The oil is circulated rapidly by a 15-in. centrifugal stirrer which sucks oil downward inside a cylindrical shield, and

[1] Research Fellow, Harvard University.

forces it up outside the shield through the heating coils. The oil bath has a tight-fitting cover from which all of the apparatus within is suspended, so that lifting the cover allows the apparatus to be removed for inspection, testing, and repair. The tight cover also makes it possible to heat the oil nearly to its flash point without great discomfort or danger from smoke and fumes.

The steam passes through a coil of eight $^1/_2$-in. seamless steel tubes, each 20 ft. long, immersed in the oil bath, and is thereby brought so close to the bath temperature that no difference can be

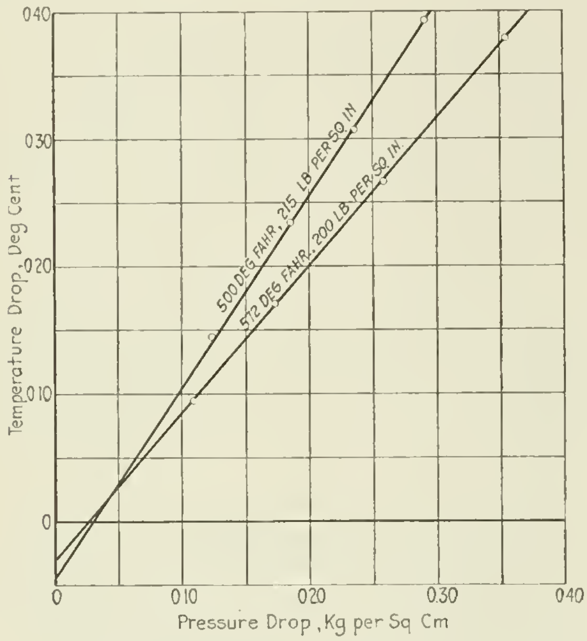

Fig. 3 Hoxton's Method of Correcting for Heat Leak

detected by a thermocouple. It then enters the "plug case" in which the measurements are taken. The plug itself is an alundum tube 1 in. in diameter, 8 in. long, with walls $^1/_8$ in. thick, closed at one end, and supported by the "plug case" at the other. The

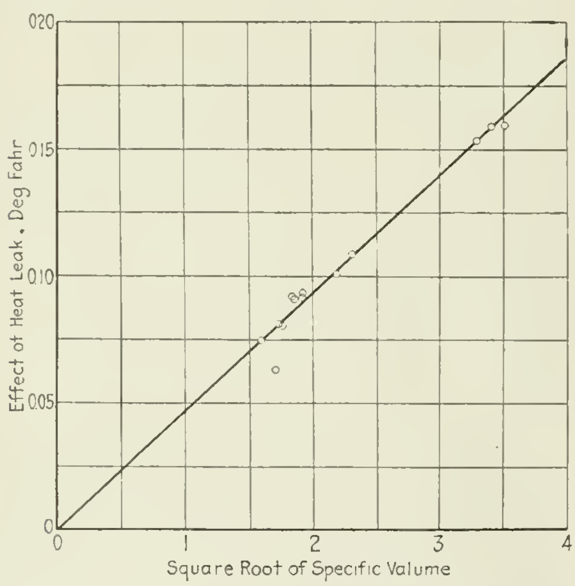

Fig. 4 Relation of Effect of Heat Leak to Specific Volume

steam, after passing the high-side pressure-gage connection and one junction of the differential thermocouple, passes around the plug and radially inward through the walls, over the other junction of thermocouple—which is placed inside the plug, near its closed end—out through the open end of the plug and out of the bath. Finally it passes through control valves into a condenser, and the condensate is weighed.

A 2-in. layer of asbestos wool provides lagging around the plug to prevent heat leak from the bath to the cooled low-pressure steam. This arrangement of the porous plug and lagging was carefully tested by Trueblood in order to get as small a heat leak as possible, and one that could be measured or allowed for, as will be shown later.

In taking measurements, readings are taken of the high-side pressure, the high-side temperature, the bath temperature, the pressure drop through the plug, the corresponding temperature drop, the rate of steam flow, and the room temperature (used in certain instrument corrections).

Observations are begun after the apparatus has been operating under steady conditions for from one to four hours, and readings

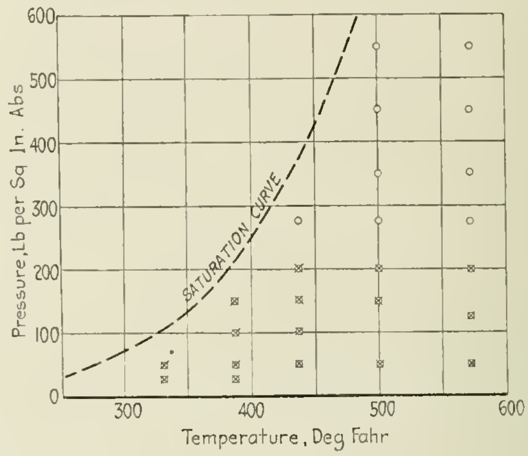

Fig. 5 Points at Which Measurements are to Be Made

of each quantity are taken as rapidly as possible over two periods of half an hour each, separated by at least half an hour. If these two sets agree closely the run is considered satisfactory and the flow is changed, keeping the high-side pressure and temperature the same as before. In this manner at least four runs are taken at different flows, with the same high-side pressure and temperature. From these runs a single value of the Joule-Thomson coefficient

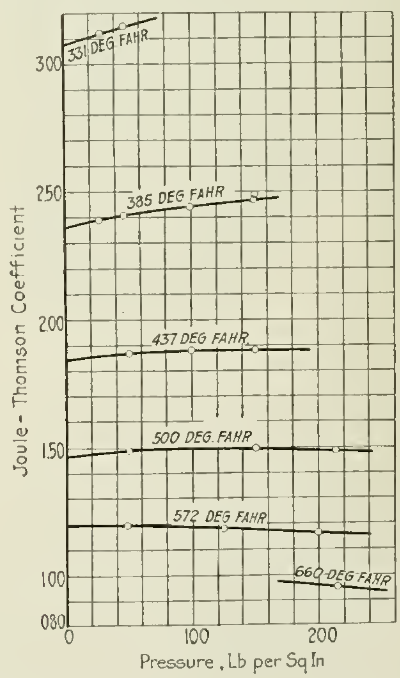

Fig. 6 Preliminary Results of Joule-Thomson Measurements

can be computed, corrected for heat leakage by one of the following methods:

1 *Trueblood's Method.* This is fully described in his paper. It consists in dividing the measured temperature drop by the measured pressure drop for each run, obtaining thereby a series of "apparent" μ's at various flows, and plotting these "apparent" μ's

against the reciprocals of the flows. These points lie on a straight line which is nearly horizontal if the flows are not too small, and the intersection of this straight line with the μ-axis (infinite flow), can be shown to be the true μ, corrected for heat leak. Fig. 2 is a sample plot of this kind.

2 *Hoxton's Method.* This method is a little easier to handle, though giving the same results as Trueblood's method. It consists in plotting the observed temperature difference against the observed pressure difference. The result, at high flows, is a straight line which, if extended, passes slightly below the origin. The slope of this line can be shown to be the true μ, corrected for heat leak, and the actual effect of heat leak is the distance below the origin at which the line cuts the temperature axis. Fig. 3 is a sample plot of this kind.

It can be proved that this intercept on the temperature axis should be nearly proportional to the square root of the specific volume of the steam passing through the plug. Fig. 4 shows that this law is closely followed by the experimental results. It is a delicate test of the consistency and accuracy of the results.

Fig. 5 shows the points at which measurements are to be made. The points indicated by crossed circles have been completed at the present writing. There are sixteen points finished and Fig. 6 shows these values plotted against pressure. On the basis of the work previously published the sign of the variation of μ with pressure is in doubt. Callendar's equation requires a rapid decrease in μ in going from zero pressure to saturation pressure. Goodenough and Heck predict an increase in μ followed by a decrease. The present work shows that the pressure coefficient is very small, whether it is slightly positive or slightly negative cannot be predicted with certainty from these results until all the corrections have been applied.

The more interesting portion of the work at high pressures remains to be done, and all the results given are subject to correction.

The Steam Investigation Program at the Research Laboratory of Physical Chemistry, M.I.T.

By F. G. Keyes,[1] Cambridge, Mass.

Before proceeding with the description of the plans for the new work on the pressure-temperature relation, the liquid and vapor saturation volumes as well as the superheated region, it may be well to refer to the earlier work carried out by Mr. R. D. Mailey of this laboratory. The preliminary work of Mr. Mailey was finished about 1912, after which the entire apparatus was redesigned on the basis of the experience gained in the preliminary measurements. The redesigned apparatus included improvements in the constant temperature baths such that temperatures to over 750 deg. fahr. could be maintained constant for long periods of time to within 0.02 deg. fahr. The bath was a prime requisite, since the purpose was to carry all the measurements to over the critical temperature, about 700 deg. fahr. During the time improvements had been made in the absolute piston type of pressure gage and experience acquired in its use.

The bomb or holder for the water or steam under measurement was retained. Steel was used by Holborn and Bauman, but for measurements wherein the greatest refinement is sought the known interaction of steam with steel at temperatures of 700 to 800 deg. makes its use undesirable. Platinum was chosen and a one-piece sphere spun over a hardwood form, leaving a neck about $^3/_8$ in. in diameter. The platinum sphere with its inclosed wooden form was heated and the wood burned out. A pair of hemispheres were now turned of steel such that when they were screwed together the spherical cavity formed therefrom made a good fit for the platinum sphere. The neck of the platinum sphere was spun out laterally and the cover, platinum-faced, locked on by means of a steel union piece, using a pure gold gasket. This bomb proved to be tight up to the highest pressure (3000 lb.) and to 800 deg. fahr. Water is of course without action on platinum and it would seem to have been ideal.

In the method employed for measuring the properties of substances whose critical temperature lies low enough one may confine the substance under measurement and at the same time transmit the pressure to the devices for measuring the pressure and volume by means of mercury. In the case of steam, however, the critical temperature lies at a point where the vapor pressure of mercury is considerable, and moreover the use of the platinum bomb with a gold gasket would prevent the use of mercury. The method actually employed consisted in confining the water with itself. A very fine copper tube of 0.01 in. bore connected the bomb with a steel cylinder contained in a constant-temperature bath maintained at about room temperature. The piston used in this cylinder was of mercury, whose level could be accurately advanced or withdrawn by the intermediary of a steel piston moving through a packing gland and advanced or withdrawn by means of a screw and nut. The total mass of water under measurement is known, but one portion is maintained always at room temperature and the other at temperatures up to the limit of the range desired. To obtain the amount of water under measurement in the bomb involves taking the difference between the total quantity and that in the cylinder with which the bomb is connected. In the superheated region where the specific volume of the steam is large, the mass of water, as steam, in the bomb will be small and comes out as the difference between two large quantities, which militates against accuracy.

The foregoing are some of the larger sources of error in the work of ten years ago. During the time that has elapsed many improvements have been made in the details of the methods used in the laboratory to measure volume, pressures, and temperatures accurately. In attacking the difficult problem of the measurement of the properties of steam the Research Laboratory portion of the task is receiving the benefit of all of the accumulated experience of these years.

The plans for the renewed work on steam include the substitution of pure nickel for platinum. Pure nickel was unobtainable in homogeneous forgings twelve years ago. This metal has been found to constitute a good choice for a number of reasons. It is unattacked by steam even at 900 deg. fahr. It is uniform in its expansivity with temperature and tough enough at higher temperatures to permit of sealing with absolute tightness. It does not alloy with mercury and hence mercury can be used to measure the stretch of the bomb with increase of pressure. The true volume of the bomb can likewise be determined at a number of temperatures by means of mercury and thus the volume of the actual bomb employed will always be known in terms of weight of mercury.

Any change in the future of the densities of mercury with temperature will thus permit a recomputation of the actual bomb volumes, although there is reason for confidence in the mercury densities as at present known.

The same general scheme of confining the steam with water will be employed, using, however, two different volumetric measuring pistons, one for the saturation dome and the other for the superheat where larger specific volumes come under measurement. The connecting capillary is of nickel swaged from larger tubing to about 0.01 in. bore.

The improvement in the volume-measuring technique is such that a volume change of about one part in forty thousand may be detected. The pressure-measuring gages are of the absolute piston type floated by oil. The constant of the gages is not determined by measuring the diameter of the piston but by direct comparison with a mercury column 31 ft. in length. The equilibrium of the piston is detected by an electrical contact device which has been continually improved during the past years. The checks at different heights of mercury column with the new gages are about one part in twenty thousand. Pressures of a fluid cannot of course be measured consistently to this precision because of the difficulties of securing equilibrium, but much has been learned concerning this latter problem so that very much greater precision can be expected than in the earlier work.

The superheated field is one of particular interest from a purely scientific point of view as well as from the engineer's viewpoint. Water is regarded by the man of science as a fluid different in its properties from substances sometimes called normal such as ether, ethyl chloride, or methane. It will therefore be of profound interest to learn whether at high superheats and high pressures water vapor is indeed different in its general properties from the so-called normal substances.

[1] Dir. Research Lab. Physical Chem., M.I.T.

The Steam Research at the U. S. Bureau of Standards

By N. S. Osborne,[1] Washington, D. C.

The part of the experimental program which the Bureau of Standards undertook was a determination of the thermal-capacity of water as saturated liquid.

This problem came to us in two parts: First, the heat capacity of water, in the range from the normal freezing point to the normal boiling point, in terms of international units of energy, was wanted to establish with greater certainty the fundamental heat unit. That is to say, the mechanical equivalent of heat. This was wanted as a basis for steam-table construction. The second part, above the normal boiling point and as much higher as it was convenient to go, the thermal capacity of liquid water was desired as a further basis for steam-table construction.

This problem was analogous to one upon which the Bureau had been previously engaged, the results of which have just materialized in the form of complete tables of thermal properties of ammonia, which have just been presented at the annual meeting of the American Society of Refrigerating Engineers.

The problem of determining the thermal capacity of a saturated liquid, water, develops into a project by which, in a single apparatus, with the identical samples of the fluid, under similar conditions, with a constant degree of precision, and without dependence on other data, an entire group of thermodynamic properties, those for the saturation condition, may be determined; and it is this experimental project upon which we are at present engaged.

We have determined a general tentative design of apparatus appropriate to make these heat measurements which consists of a closed container for the fluid, made of a metal which will withstand the combined temperature and pressure without permanent deformation. The interior space is provided with an electric heater. The container in which this heater rests is also provided with an agitator, to distribute the heat so added, and promote equilibrium. The container is closed, except for outlets that provide it with valves, which may be opened or closed to permit the addition or withdrawal of portions of the fluid. If the necessary auxiliary instruments and devices are provided, we may observe the temperature of the container and its fluid content when in equilibrium, the pressure at any instant, the initial and final amount of fluid, the entire amount of heat added during any period of time, which will include that due to thermal leakage and to the energy dissipated in stirring.

The experimental processes which may occur, under the control of the operator, in connection with these observations, are three: First, by adding heat, keeping the mass of content in this calorimeter constant, its temperature can be changed; and, in addition to that, the fluid may be withdrawn from the calorimeter in two ways—either as vapor or as liquid, and, simultaneously, either by adding the necessary compensating amount of heat, the temperature may be kept approximately constant, or by adding no heat at all, the temperature may be changed.

The ones that we will use are the ones where we keep the temperature nearly constant and transfer fluid.

The experimental results of the three types of experiments can be expressed in terms of specific thermal properties of the saturated fluid, as three quantities, and the properties that come into these are the heat content of the liquid, the internal energy, plus the PV, and an expression including the latent heat, and the two specific volumes of liquid and vapor.

To the experimenter, the interesting thing about this is that all these results are obtained without the necessity of knowing either the heat capacity of our calorimeter or its volume. All that we require is that both of these things shall be definite; that is, that the heat capacity shall repeat itself at the same temperature and pressure, and the volume shall repeat itself.

In determining the design of the apparatus to accommodate this, a great many details developed, which had to do with the proper guarding against external influences on the interior part where occur the experimental processes to be observed. Other features are concerned with the control of the processes themselves, so as to make them conform to such specifications as the analysis requires. Two features illustrate the nature of the problems which arise.

In the first place, a vigorous circulation of the liquid in the calorimeter is desirable in order to attain equilibrium quickly, and so that the whole interior of the apparatus shall be bathed with the agitated liquid and its surfaces kept at a uniform temperature. Thus by controlling the temperature of the envelope, we may evaluate the outstanding thermal leakage that would otherwise exist. This circulating stream of water would be lifted to the top of the calorimeter, in order to bathe the entire interior surface. This leads to another important feature—that of locating in the top of the calorimeter, where it is continually bathed with the flowing stream, an evaporator, so that saturated steam may be manufactured and withdrawn from the calorimeter without disturbing the equilibrium within. It is proposed to furnish this circulation by a turbine pump, the duty of which will be about one three thousandth of a horsepower.

To provide means of assembling in the calorimeter parts such as these which I have mentioned, a metal shell has been developed which can be put together and made to stay tight, without resorting to any soldered joint. It is made out of a special alloy of copper and nickel—eighty per cent copper, and twenty per cent nickel. The two cup parts are threaded with a right- and left-hand thread, and one part has a groove one thirty-second of an inch in width in it; the other has a tongue which is made to nicely fit into that groove. The two are drawn together by means of a correspondingly threaded metal band, upon a ring of gold wire, one thirty-second of an inch in diameter. When we put on this double-threaded band with a powerful wrench, sufficient pressure is put on the gold washer to make it conform to the surfaces of this groove, and to make the shell tight, up to the pressure where the forces are balanced between the tension in this band, acting on the gold washer, and the forces of the hydrostatic pressure within, acting on the shell. We have found that the metal has properties to stand a pressure of 3000 pounds to the square inch. The joint held up to about 2400 pounds to the square inch, which gives us a very fair factor of safety.

The question of interaction of the water and the material in the calorimeter, can, with this device, be very well taken into account by gold plating the inside of the calorimeter and the other installation to go within.

[1] Bureau of Standards.

The Development of Machine Tools

(Continued from page 154)

turret. This improvement made possible the modern automatic lathe and similar machines. It is a tribute to the genius of Spencer that his very first automatic machine was a great success. While he is known and remembered largely in connection with the invention and production of firearms, Spencer's greatest contribution to machine production is the universal cam wheel, a device which was never patented.

These, then, are the three great advances in transfer of skill in machine tools. Maudslay's slide rest and Stone's turret are used in the construction of semi-automatic machinery more frequently than any other machine elements, while the combination of these two with Spencer's universal cam wheel is the basis of practically all automatic machines.

The importance of these inventions and improvements cannot be overestimated. The period of their development from Maudslay to Spencer was a little over one hundred years. These inventions with others of the same period embody the results of the observation, experience, and effort of the greatest group of mechanics in the history of the human race. Their achievements made possible the work of such men as Hartness, Swasey, and other great builders and laid the foundation of modern industry and transportation. Selfishness, stupidity, and lack of knowledge have as yet stood in the path of the full realization of the benefits these inventions can bestow upon all humanity. It is to be hoped that a wiser generation will be able to solve the problem of distribution in such a manner as will permit the use of these modern productive methods to fill the land with plenty.

Means for Vocational Training for the Industries[1]

Industrial Education in Extension, Correspondence, Apprentice, Shop Training, and Various Other Schools—Report of A.S.M.E. Committee on Education and Training for the Industries

BY THIS report the A.S.M.E. Committee on Education and Training for the Industries seeks to disclose the present status of industrial education and training in order to secure expert attention and advice to the end that the average efficiency of the process may be raised. The Committee believes it not unreasonable to expect that careful consideration given to this report by all concerned in promoting industrial education will result in a coördination and simplification which may be suggestive of a standard code of procedure in vocational training. This may not pass beyond the statement of governing principles associated with a prescription of the steps in the process which the end requires. At any rate, the Committee is convinced that much good will result from the discussion which this report invites.

As will be seen from the papers constituting the report, industrial education and training of a vocational nature is susceptible of classification. The considerable task of collecting and arranging the information herein presented was performed under the individual supervision of three members of the Committee as indicated by the authorship of the several papers, and to these three members and Director Moyer, the Society is under a debt of gratitude.

In general, industrial education is conducted either inside or outside the works, and sometimes uses both plans coördinately. The distinction is recognized, therefore, between apprenticeship conducted within the works and vocational, trade, and evening schools outside of the works. Correspondence work and extension schools, strictly speaking, belong to the latter of the two classifications, although these are given separate treatment in the accompanying papers on account of their special character. In each paper typical courses are presented to illustrate what may be termed "standard practice" of its kind.

It has been estimated that an exhaustive survey of the whole field in the United States to be of value in pointing a conclusion would probably cost $100,000. With no funds available and convinced that the time is not yet opportune to warrant a procedure that calls for the solicitation of funds, the Committee presents the results of its studies with the belief that the picture thus afforded will appeal to the imagination and give a fairly definite idea of conditions so far as available statistics are concerned.

EXTENSION AND CORRESPONDENCE SCHOOLS

By JAMES A. MOYER,[2] BOSTON, MASS.

[The accompanying report by James A. Moyer, director of University Extension in Massachusetts, is made by request of the Committee on Training for the Industries of The American Society of Mechanical Engineers. The first thought in relation to this is to express no opinions as to the preëminence of any school or any state but simply to give the facts that will form the basis for a larger report on Correspondence and Extension Schools in the United States. A full report in detail would demand visits to every state in the Union, and several volumes. Consequently, no attempt has been made to cover more than a fair outline of what may be found.

On account of his wide experience with extension teaching, and also on account of his connection with the Massachusetts State Department of Education where records are kept of all correspondence schools and extension departments in the United States, Mr. Moyer is very well qualified for a study of this subject. There is a slight difference between a correspondence school and a course in extension work. The latter may include the former. Correspondence instruction lacks the contact among students that promotes discussion and supplies stimulus for study, but it makes up for that in the serious purpose of every student and in what must be confessed is superior instruction. A correspondence school can afford to employ the very best talent in the country for preparing the textbooks and can lend to the work a degree of technical skill that one cannot find in the average college. The extension schools are usually connected with universities. In Massachusetts the first conception of an extension department was the education of workingmen in the industries, and to that end the technical courses were those first established. But this was in an industrial state, dependent upon technical skill for a large part of its success in manufacture. There has been a steady growth, however, toward other subjects, and Mr. Moyer has under his charge what really amounts to a university of thirty or forty thousand students.

The question might be asked, have these schools reached the height of their usefulness? Will they progress by improvement into larger fields? Their work is extremely useful, as they open the way to an education for thousands of men and women who have no money to go to college and who can profit by this kind of absentee study.

I have suggested to Mr. Moyer that he go into some details with regard to his own work as typical of many extension departments of states. If his report stimulates active thought on this whole subject by members of the Society, it will have amply served its purpose.—IRA N. HOLLIS.[1]]

CORRESPONDENCE courses in industrial subjects have been an important part of adult education for more than thirty years, and many of the courses have received wide publicity. During this thirty-year period one well-known correspondence school has enrolled nearly three million students, mostly in industrial subjects, and this same school, during the last year, sent out more than one million lesson assignments.

Besides the privately organized correspondence schools, nearly every state now has a correspondence-school system supported by taxation. These state-supported institutions are usually organized as a department of the state university, where there is one. In states like Massachusetts and New York, however, where there are no state universities, the correspondence instruction is organized in the state departments of education. Most of the state-supported institutions giving instruction by correspondence, and also some of the privately supported institutions, have given this kind of teaching the name "University Extension," which usually includes also class instruction for adults, as organized in large centers of population to take the place of correspondence instruction.

All correspondence instruction is conducted through the mails. By this method the student is sent a supply of specially prepared texts. At the end of each text a series of questions are asked which the student is requested to answer, after having carefully studied the subject-matter of the texts. These answers are sent to the correspondence school for correction. When these have been carefully corrected and graded by instructors, the percentage given is marked on the corrected paper and returned to the student so that he may see just where he has made errors.

It should be emphasized that a correspondence course comprises material organized as a basis for the instruction of a student at a long distance. It is therefore a system of instruction in which the assignment material is common to all students, but considerable variation is possible on account of the flexibility and adaptability inherent in this system of instruction. In the informational courses the differences in maturity, native ability, prerequisite preparation, etc., can all be taken care of readily and the course fitted to the need of the individual. The resultant body of papers

[1] Report of the Committee on Education and Training for the Industries, presented at the Annual Meeting, December 4 to 7, 1922, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

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[1] President, Worcester Polytechnic Institute, Worcester, Mass. Past-President Am.Soc.M.E. Mem. A.S.M.E. Committee on Training for the Industries.

worked out coöperatively between teacher and student makes a volume peculiarly fitted to the individual needs of each person. This statement is important because in the minds of many people a correspondence course is incorrectly conceived of as a series of tests and examinations and a grading of the papers written in such tests. Work that does not rise above this procedure is not correspondence instruction. Where it follows correct procedure, the correspondence method supplies one of the most effective means by which adults may keep abreast in any informational field. Correspondence students may include those who have had little more than a common-school education, as well as those who have taken their advanced degrees from the eminent universities of the country, numbering men and women conspicuous in many professions.

Extension Classes

Extension classes are locally organized. The instructors are either members of the faculty of the university or school conducting the classes, or persons living in the vicinity in which the class is conducted, provided, of course—in the latter case—that qualified persons are available. This instruction is conducted by ordinary educational procedure. An effort is always made in extension teaching to adjust the instruction as much as practicable to the individual needs of the individual student.

Extension classes differ from residence classes in that membership in them is open to all who can give reasonable evidence of their ability to profit by such instruction; and in that these classes afford, so far as is possible in classroom work, individual attention to individual needs.

The courses offered by either of these plans range in price ordinarily from \$3 to \$150, depending largely on the cost of the text materials furnished, and whether or not the institution giving the course is supported by taxation.

The instructional material consists, as a rule, of lesson pamphlets prepared and published by the university or school. Each pamphlet includes from one or two to as many as twenty-five pages of explanatory or "lecture" material, one or more pages of questions which the student is to answer and submit for correction, and whatever directions the student may need as to the way in which lessons are to be prepared. Usually each course is so arranged that it may be used with equal facility either for class or for correspondence instruction.

The rapid expansion of this work has been favored from the first by the type and range of subjects in which courses are offered. For the demand for education of this kind is concerned not with particular, closely defined groups, but with the whole adult population. To be sure, in some quarters the demand is more pressing as the lack of essential education is greater; but everywhere, among men and women of every class and occupation, there is evident the desire for further opportunities to study. The bulletins describing the courses offered by the largest correspondence and university extension institutions contain upward of one hundred and fifty courses, including such section headings among the industrial courses as mathematics; drawing; steam engineering; electricity; structural engineering; textiles; natural science; commerce and management; history and government; and business economics. Within each group are comprised, as far as possible, courses ranging from the most elementary to those of college grade. The breadth of such programs, when offered by state institutions, has resulted in making every man and woman in the state a prospective student. In that case the state is offering something for everybody, and consequently the idea of continuation education has penetrated into every industry or business. The mechanic, the fireman, the engineer, the business man, the clerk—from the unlettered immigrant on the one extreme to the college graduate on the other—all are represented in the enrollments.

The problem of making these courses widely available to classes is one of reaching fairly compact, well-centralized groups, and the method of approach is accordingly direct. Agents of the university or schools consult with industrial executives, the representatives of business and social organizations, and school superintendents, and through them discover for what subjects each community has a genuine need. Instructors are then appointed, according to the nature of the courses, from college faculties or from among commercial and industrial specialists. And it is significant of the whole university-extension scheme that an instructor's formal connections and affiliations count less toward his appointment than his ability to give vital, effective instruction.

Usually study rooms and lecture halls in local school buildings, provided by the courtesy of the school departments, serve as class meeting places; and in some instances as many as half a dozen university-extension classes meet in a building on a single evening. When a class is of special interest to the employees of a certain industrial plant, it is frequently arranged to meet in the plant itself. Public-library halls and clubrooms are also used on occasion, but always with the understanding that every university-extension class, whether held in a public or a private building, is open to any resident of the state. The chief consideration in the choice of the meeting place is this: that it enables the institution to reach the people where they are.

As a tangible evidence of achievement, each student who successfully finishes a course either by class or by mail is awarded by many institutions a certificate giving the name and grade of the course, and the number of lessons completed. On certificates for all college-grade courses, the work done is usually stated also in terms of equivalent semester hours.

Advantages of Correspondence and Extension Courses

A result of correspondence courses and university extension classes less easy to estimate in formal values is the unexpected spirit of democracy to which they have given rise. Social groups which ordinarily acknowledge no common interests have learned to know of each other through the common interest in correspondence lessons; and those brought together in classes, having profited by the same instruction, have been led through class discussion to compare their views with the utmost cordiality and freedom. A non-technical course in the care and operation of gasoline automobiles, for example, has provided a common ground of interest for men and women of every occupation and walk of life. But perhaps the most effectively democratic are those classes for the training of foremen and executives in oral English, for in these particularly the students not only meet together but discuss with each other matters of general interest. There is something peculiarly personal and cordial about these classes, where each member at some time during the course addresses his fellow students on a subject of his own choosing. And the method as well as the membership of these classes is democratic, for the students both recite and criticise recitations, while the instructor, acting as a sort of moderator, takes the platform only for brief intervals, to make suggestions. From these recitations all the restraint of formal address is lacking; if other members of the class disagree with the speaker's opinions, they are at liberty to offer their own in opposition. Incidental debates are frequent; and in the interest of discussion, every shadow of social distinction vanishes.

The correspondence courses, while affording no such opportunity for student-to-student contact, are no less large in their appeal. As may be supposed, there was at first, among persons familiar only with the methods of high schools and colleges, some little tendency to regard correspondence instruction as a second-rate substitute for class work. But seldom did that tendency amount to prejudice. When class instruction in a desired industrial subject was clearly not available in a community, even the skeptical preferred to give the correspondence method a trial rather than to forego the chance of any instruction whatever. And the first experiment was usually convincing.

The student quickly came to recognize that correspondence study has its own peculiar advantages—that it is available to him at any place and at any time; that each paper he submits gets the individual and undivided attention of an instructor; that "bluffing" is out of the question—he must prepare himself on every part of the lesson; and finally, that he may set his own pace, unhurried by more brilliant students and unhampered by sluggards.

By artisans and mechanics, correspondence courses are usually accepted without question. Perhaps because the advertising of correspondence schools has long been directed chiefly at them and because many of them have already had experience in the "learn by mail" method, they have evidently had the start of their neighbors in appreciating its advantages. Most of them willingly accept

it as a substitute for class instruction, and not a few declare that they actually prefer it.

Recognizing that the common fault found with correspondence is that it lacks "personal contact," correspondence schools have set before themselves the ideal of making and maintaining between instructor and student a genuinely personal relation. That ideal is freely expressed; and every correspondence instructor is trained to respect it. With the first assignment of each course, the student is asked to submit an information sheet on which he has recorded such matters as name, address, age, occupation, and the extent of his previous schooling. This information the instructor enters on his personal records and reviews from time to time, so that he keeps in mind a rough mental sketch of the student with whom he is dealing. Some instructors who handle the papers of from one hundred to one hundred and fifty students yet maintain so intimate an acquaintance with each as to recognize his handwriting and to remember what have been his individual difficulties. This system has proved to have the double advantages of keeping the instructor constantly in touch with the student's progress so that he may more effectively prescribe and advise, and of making the student realize that his instructor knows him personally and is in a position to understand his peculiar difficulties.

But the ideal of personal helpfulness does not stop with the instructor; it is written into every course. On whatever subject, the material of the lesson pamphlet must be human, wholesome, and practical. Hypothetical problems, so far as possible, are avoided, and their places taken by problems based on fact. A certain course in textile mathematics, for example, says not, "Suppose that there are 580 looms in the ——Mill at Lawrence," but, "There are 580 looms in the —— Mill." And there are. The student gets not only a problem in mathematics, but along with it reliable facts about the textile industry.

So it is with the other courses: the instruction is concrete and tangible. The aim is to make the language of each assignment unmistakably clear; and the lesson requirements are such that the student shall be capable, under ordinary circumstances, of carrying them out. If, in spite of careful editing and supervision, faults appear after a course has been put into circulation, the instructor is on the watch for them. When his experience with students leads him to believe that a course might be improved, he makes a detailed report, in which he states what is wrong, and how, in his judgment, the fault may be corrected. If his criticism is found to be just, the course is revised.

The personal touch with students is also maintained in another way. Each month a news letter, so-called, is sent out to every person enrolled in the correspondence list. Sometimes it is merely a friendly letter of encouragement. Sometimes the letter is editorial in nature, touching, perhaps, upon the qualities of good citizenship. Sometimes it is a page of suggestions as to methods of study. Intrinsically, the news letter is a small affair, hardly to be counted in comparison with the actual work of instruction, but it seems to remind many students that in the staff of instructors, whom they may never see, there is a cordial personal interest for their success; in short, they are not dealing with a "soulless" organization.

Results of University-Extension Work in Massachusetts

The results to which these methods have led are encouraging. We have mentioned already how general has been the appeal of the courses, and how democratic has been their influence. Taking Massachusetts as a typical case, and not at all by way of expressing a superiority, but rather in order that the members of the Society may get a clearer understanding as to how this kind of instruction has grown—the advance has been almost in geometrical progression: At the end of the first year from its establishment, the Division had only a few more than 3000 students; today the total enrollment is well above 100,000, and it is significant of growth that more than a third of that number represents enrollments for the past year alone.

But numbers by themselves are less important than the geographical distribution of students and classes. It would have been comparatively simple to secure heavy enrollment by concentrating effort in a dozen or less large cities and towns, neglecting meanwhile the more remote corners of the state. This, however, has not been done. Each year active effort is directed toward filling in the gaps—toward carrying instruction into towns where university extension has not before been well represented. In consequence, there is hardly a town in the state where classes have not been held, and the post offices are few which do not handle the mail of university extension correspondence students.

Not only among students but also among many organizations and many individuals generally interested in education, the university-extension idea has spread. In certain cases these have been reached by special services such as the distribution of visual-instruction material and the publishing annually of a list of university-extension lectures for the use of women's clubs, parent-teachers' associations, and like organizations. But of even greater importance is the contact which has been established with the employers of men and women studying correspondence and extension courses. Whenever a student completes a course, unless he objects, his employer is notified and asked that, if possible, the student be given a word of commendation. The response has been admirable. Every mail brings letters from employers in which they express their appreciation for this educational work, and, frequently, report that they have personally talked with the student and have arranged for his advancement at the first opportunity. And in almost equal volume come letters in which the students themselves tell of promotion made possible through university-extension study. The student is thus encouraged to continue the work of self-improvement, which he sees has won for him favorable notice from his employer; and the employer himself is often led to ask that university-extension classes be established in his city or town for the training of his other employees.

And so, at the conclusion of its seventh year, the Division can look back with some satisfaction at the training of more than a hundred thousand students, and forward to new opportunities for services that are daily opening before it. The work of the past, by establishing contacts, has blazed a trail for the work of the future; and the time seems not far distant when every community in Massachusetts shall make its annual demand upon university extension.

Extension Work in Wisconsin

In the University of Wisconsin the University Extension Division was organized on its present basis as an extramural college with a dean and separate faculty in 1906. Some forms of extension teaching have been conducted by this Wisconsin institution since 1892. Much of the present development by correspondence study courses and extension teaching in classes has been due to the pioneer work of this university. Louis E. Reber, Dean of the University Extension Division and a member of The American Society of Mechanical Engineers, has been in responsible charge of this institution and deserves a great deal of credit for present accomplishments in this form of education, not only in Wisconsin but in all other states as well. His contributions to this subject deserve special mention. In this connection, it is interesting to note that the International Correspondence School was organized within a year of the time that extension teaching was first established in Wisconsin.

Summary of University-Extension Service in Various Institutions

Replies to a questionnaire sent to various institutions giving correspondence or "extension" class instruction have been carefully studied and grouped in Table 1. Most of the questions asked were more detailed than the headings of the columns, and therefore more explanation is necessary. The heading of column (1) means the number of years since the establishment of correspondence or "extension" class instruction in the institution. Columns (2) and (3) refer to the kind of instruction offered by the institution, that is, whether the teaching is exclusively by mail, which is called correspondence instruction, or whether it is given in classes which are not regularly organized to take the standard residence courses of the institution. These classes differ from residence classes in that the enrollment is usually permitted of adults who can be expected to profit by the instruction without, however, the educational tests of college entrance examinations, and the class is usually organized at a considerable distance from the city or town in which

TABLE 1 REPORTS FROM INSTITUTIONS GIVING CORRESPONDENCE AND EXTENSION-CLASS INSTRUCTION

Name and Address of Institution	Years Established	Kind of Instruction		Students 1921–22	Total No. Students Since Organization	Student Completions		Cost to Student	Per Cent Students in Industrial Subjects	Positions Graduates Enter	Results of Training	Students Transfer Without Charge	Follow-up System for Encouragement
		Corresp.	Class			Corresp.	Class						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Alexander Hamilton Institute, New York, N. Y....	13	Yes	No	48,800	167,000	0[1]	0	$136	...	Executives	Training for responsibility	Only one course	Yes
American Commerce Association, Chicago, Ill.....	8	Yes	No	....	....	?	0	$147	...	Executives	....	Yes	Yes
American School of Correspondence, Chicago, Ill..	25	Yes	Yes	18,100	104,900	5,500	10	$20–$161	60	Superintendents and executives	Interest in production and personnel	Transfer fee $3	Yes
American School of Landscape, Architecture & Gardening, Newark, N.Y.	6	Yes	No	300	800	120	0	$68–$76	35	Foremen and superintendents	....	Only one course	Yes
Carnegie College, Rogers, Ohio..................	20	Yes	No	500	8,000	600	0	$25–$100	25	....	....	Yes	..
Chicago Technical College, Chicago, Ill............	20	Yes	Yes	2,500	10,000	6,000	?	$25–$90	100	Draftsmen and superintendents	Better training for technical positions	Yes	Yes
Columbia University, New York, N. Y............	2	Yes	Yes	12,000	60,000	....	....	$10–$100	?	....	....	Yes	Yes
Hays School of Combustion, Chicago, Ill........	4	Yes	No	550	3,000	300	0	$78–$98	100	Superintendents and combustion engineers	Better training for operating positions	Only one course	Yes
Industrial Extension Institute, New York, N. Y....	3	Yes	Yes	....	5,000	?	?	$135–$160	100	Executives	Better training for executive positions	Only one course	Yes
International Correspondence Schools, Scranton, Pa....................	31	Yes	No	97,300	2,700,000	45,000	0	$65 (avg.)	100	Superintendents and executives	Training for advancement	Yes	Yes
Iowa State College, Ames, Iowa..................	9	Yes	Yes	2,400	4,000	20	2200	37½ c. a lesson[2]	100	Industrial	Better training for industrial positions	Yes	No
Knights of Columbus Schools, New Haven, Conn.	3	Yes	Yes	98,600	233,000	314	167,701	Small fees	50	Trade and commercial	Training for advancement	Yes	Yes
LaSalle Extension University, Chicago, Ill........	13	Yes	Yes	60,000	360,000	400 a mo.	500 a mo.	$36–$197	17	Executives	Better training for responsible positions	Yes	Yes
Mass. Department of Education, Boston, Mass....	6	Yes	Yes	36,800	114,700	10,900	36,500	$1–$10	30	Foremen, superindents and engineers	Training for responsibility	Yes	Yes
McLain's System, Milwaukee, Wis..............	14	Yes	No	238	4,400	3,300	0	$135–$150	100	Foremen, superintendents and inspectors	Better training	Yes	Yes
Nova Scotia Technical College, Canada...........	1	Yes	No	189	189	48	0	$2–$14	50	Varied	....	Yes	Yes
Pennsylvania State College, State College, Pa.......	10	Yes	Yes	13,300	104,000	?	50,000	$3–$10	60	Superintendents and engineers	Training for foremen	Yes	Yes
United Y. M. C. A Schools, New York, N. Y........	12	Yes	No	9,000	33,000	?	0	$60 (avg.)	40	....	....	Yes	Yes
University of California, Berkeley, Cal...........	9	Yes	Yes	21,100	62,800	?	?	$6–$12	20	....	....	Yes	Yes
University of Chicago, Chicago, Ill................	31	Yes	No	6,500	30,000	15,000	0	$19–$50	20	....	Better training	No	Yes
University of Colorado, Boulder, Col...........	10	Yes	Yes	2,000	6,600	60	2,200	$3	50	Foremen, superintendents and engineers	Better training	Yes	Yes
University of Kansas, Lawrence, Kan..............	12	Yes	Yes	2,700	14,300	4,000	2,600	$4–$20	10	Foremen and superintendents	Better education	Yes	Yes
University of Minnesota, Minneapolis, Minn.....	9	Yes	Yes	5,800	30,300	1,300	22,400	$5–$17	20	Draftsmen, surveyors and superintendents	Better engineering training	No	Yes
University of Missouri, Columbia, Mo............	12	Yes	Yes	800	6,100	3,100	300	$4–$10	...	....	....	Yes	Yes
University of North Carolina, Chapel Hill, N. C..	2	Yes	Yes	400	475	....	....	$6.50–$12	20	....	....	Yes	Yes
University of Tennessee, Knoxville, Tenn.	Beginning this year									Beginning this year			
University of Wisconsin, Madison, Wis...........	16	Yes	Yes	29,400	79,000	40%	50%	.62½ c. per lesson[2]	25	Superintendents and engineers	Increased efficiency	Yes	Yes
Washington State College, Pullman, Wash..........	3	Yes	Yes	300	1,000	200	300	$3–$10	20	Widely varied	....	Yes	Yes
Washington University, St. Louis, Mo.............	7	No	Yes	1,800	4,000	0	2,000	$10–$30	50	Foremen and superintendents	....	...	No
Wilson Engineering Corporation, Hanover, Mass..	10	Yes	No	200	3,200	?	?	$70–$220	100	Steel and concrete engineering	Better training	Yes	No

[1] No examinations or certificates.
[2] Necessary textbooks extra.

the parent institution is located. In column (4) are tabulated the number of students who received instruction in the school year 1921–1922; and, on the other hand, in column (5) are recorded the total number of students who have received instruction in the institution since its organization or establishment. Columns (4) and (5) include, therefore, the total enrollments of both correspondence and class students for the times specified. "Student completions" as referred to in columns (6) and (7) means the number of enrolled students who have satisfactorily completed their courses either by correspondence or in classes from the time of the organization of this form of instruction to the date of these reports (about July, 1922). There is considerable variation of practice in the institutions included in the tabulation as to the kind of record for "completions." Some institutions give certificates and others give only "credits" on the records of the institution. Some courses are also much longer than others; even the same institutions will offer some short courses and some long courses so that a high record for completions obviously means more when referring to long, rather than short, courses of study. Column (8) does not mean the cost to the institution for instruction, but is the amount charged students for enrollment, and although there may be exceptions, includes as a rule the text materials that the student actually requires. In some cases where the necessary text material is obviously extra, this has been noted by reference to a footnote. Column (9) refers to the percentage of the total number of persons enrolled in the institution for both correspondence and "extension" class instruction who are taking industrial (engineering or industrial trade) subjects. Column (10) is under the heading "Positions Graduates Enter" and the replies were not satisfactory for tabulation because of the great variety. The reply of one institution was, "Practically all are in industries;" and three others replied, "Various." The tabulation of this column, therefore, gives very little useful information. Column (11), headed "Results of Training," is an abbreviated statement for the following question: "What effect have these schools (meaning those giving correspondence and extension-class instruction) upon the education of foremen?" Some replies were received which could not be stated briefly enough for tabulation. For example, the University Extension Division of

the University of Wisconsin reports as follows: "It has a wholesome and stimulating effect. Where the instruction has been specifically organized as foreman training instruction, the result has been to increase their efficiency as a direct applied result. Where the courses have been general or avocational the instruction has added to the resources of the student in ways that are equally valuable as compared with its having only the vocational bearing." The correspondence school which has reported the largest enrollment has sent an explanation of this question in the following interesting paragraph: "As explained in our preceding answers, most of our students are already engaged in occupations of various sorts at the time they enroll for our courses. For this reason, we feel safe in saying that practically every journeyman in any trade enrolls for a course with a view to bettering his position. A machinist, for example, usually enrolls for a course in mechanical engineering or a closely allied course with a view to becoming a shop foreman. Furthermore, we have a course for foremen. This course deals mainly with the employing and handling of labor, safety fundamentals, and ten lessons which are entitled 'Training the Executive.' A man enrolling for this course is supposed to have mastered the technical end of his trade, or else he would not occupy the position of foreman. To sum up the answer, we feel that our school plays a very important part in the education of foremen." Column (13) refers to methods of instruction and is more interesting to educators than to persons engaged in industry.

SCHOOLS FOR APPRENTICES AND SHOP TRAINING

By R. L. Sackett,[1] State College, Pa

The object of apprentice training is to train a sufficient supply of young men to meet the need for skilled employees, including foremen and superintendents. It is believed that thorough training stabilizes employment, reduces turnover, gives a better understanding of elementary economics as applied to industry, and tends to "create a greater interest in and loyalty to the concern."

A number of developments have occurred within the past year indicating an appreciation of the need for apprentice training. The Industrial Association of San Francisco, for instance, an organization of employers, because of the difficulty in obtaining sufficient skilled labor and the high wages demanded, has been led to establish schools for plasterers and plumbers. They plan to open other schools for bricklayers, steam fitters, carpenters, electricians, and others. Out of 75 who responded to the first call for plasterer apprentices, 25 passed the preliminary tests. During the training period of 12 weeks, the trainees are paid $2.50 per day of eight hours and are taught by skilled workmen. At the close of the course they are put on regular work at good pay, and at the end of a year are to be rated as journeymen.

In training plumbers the plan is somewhat different. The apprentice has two weeks of schooling, then goes as a helper for four weeks on real jobs and then returns to the school.

The report says that the association believes that it can train men to be master craftsmen in 12 to 18 months, whereas three to four years have been demanded in the past.

The New York Building Congress Apprentice System

The most extensive program of apprentice training that has been recently developed is one prepared by the New York Building Congress, which is an organization composed of representatives of the architects, builders, and trade unions. A committee on apprenticeship was organized in January, 1922, "in response to a demand on the part of the building industry to develop men better trained in their craft and in citizenship than present-day trade conditions provide or permit."

The Committee states the purpose of the movement as follows:

> The Committee was established for the purpose of fostering the development of the apprenticeship in the building trades, not by dictation, but by acting in an advisory capacity with similar committees from the various interests represented in the Congress.
>
> The Committee proposes to coöperate with all other committees, organizations, and movements of trade, labor or educational interest, by bringing their activities together and overcoming the difference or inertia that has existed and which has done so much to handicap, if not to frustrate, the best interests of training in the building trades.

The policy and the general plan have been adopted by both the New York Building Trades Employers Association and by the Building Trades Labor Council, representing the unions. The joint plan is in operation and was first applied to woodworking apprentices after the carpenters unions had approved the idea. The general plan of the apprenticeship is for the apprentice to learn his trade on the job and receive his instruction in related technical studies during part-time attendance at school. The intention is to utilize the public continuation and evening schools so far as practicable but where such coöperation cannot be obtained the Congress will open its own schools.

There is sufficient evidence of an adequate supply of apprentices ready for training, and plans are being made for the organization of training for plasterers, bricklayers and other trades as soon as practicable.

This movement by the New York Building Congress has the support of financiers, contractors, and union labor and it has aroused widespread interest in the problem of supplying an adequate number of skilled mechanics and artisans. There is an encouraging sign in the announcement by the Committee that—

> The employers see the need of a constructive and sound system for recruiting skilled help and the unions realize that the trades should be dignified with a true educational merit and background.
>
> It is proposed to proceed carefully and to develop along other occupational divisions in the Building Trades until the entire field is covered, our purpose being to expand gradually so as to build up a system of good sound training that will not only meet the needs of the business but also provide an educational opportunity for our young men.

Building-trades magazines and a wide variety of associations in other cities have expressed their interest in and have endorsed the plan. It is the most conspicuous development of the year in its line. It marks the confession by employer and unions of a recognized need; it is an outstanding evidence of possible and desirable coöperation and it is an acknowledgment that there are educational methods which will expedite the preparation of skilled men.

Railroad Apprenticeships

The railroads have been from the first strong advocates of an apprentice system. They have two classes, namely, those having a common-school education, and those who have been graduated from a technical college.

Those with a common-school education are given class work in mathematics, mechanical drawing, physics, and elementary mechanics along with their shop work.

Those who have a technical education are put on more advanced repair, maintenance, design and construction—principally in the motive-power departments.

The pay of apprentices on railroads has been increased until it represents a fair wage.

Industrial Apprenticeship

In 1918 the Westinghouse Electric and Manufacturing Company, of Pittsburgh, added an apprentice drafting course to its educational work.[1] The course consists of two years of eight terms of three months each. The class periods are two hours in length and classes meet three periods per week. The following information was received, which will make clear the object and methods employed by a company which has conducted shop and apprentice training for many years.

The entrance requirements specify high-school graduates or the equivalent.

The apprentices spend the first few weeks in the Educational Department where they are given a very intensive course in tracing. They are then transferred to one of the Drafting Divisions where they remain for the first year, after which they are transferred to the shop and scheduled through the Pattern, Foundry, Forging, Machining, and Assembling Departments for the next six months. This enables them to acquire the actual shop experience so essential to designing. After completing their shop experience they are

[1] Dean of Engineering, Pennsylvania State College. Mem. Am.Soc. M.E.

[1] The details of this curriculum may be obtained on request from the Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

brought back to the Drafting Division for the remainder of the course.

The terms in general cover Objects of Drawing, Drawing System, Hand and Machine Tools, Patternmaking and Molding, Shop Practice, Materials and their Application in Manufacture, Development and Sections, and Clearances and Allowances. The mathematics in the course range from the fundamentals of arithmetic to the strength of materials in concrete problems. It might be well to mention the fact that the aim is first to make men, and that the various processes are accordingly used to instruct the boys, rather than to teach the processes.

When the course is completed, the graduates are transferred to the Engineering Department as regular employees.

Fifty-two apprentices have been enrolled in the course at this writing. Twenty of this number are still with the company, making the total turnover from the very beginning of the course, four years ago, only 61.5 per cent. Eleven have been graduated and three of their number have entered college. The remaining eight are still in the Drafting Office. Ten left the course on account of remuneration and three of them have returned. Of the twenty remaining with the company, six have been there over three years; five others have been there over two years; and the remaining nine have been there over one year. Only one of the total number was discharged.

This company also has apprentice courses for machinists, toolmakers, foundrymen, patternmakers, electricians, and junior engineers.

The applicant for trades training is interviewed by at least two different individuals and is given a simple test in mathematics. Those accepted are placed on probation for a period of three months. Their record is checked monthly by a trades apprentice committee and at the end of three months a definite decision is made as to whether an agreement shall be entered into between the young man and the company. If the young man and the company desire, a contract is entered into at this time outlining the obligations and duties of both parties. The apprentice is then placed in a special department in the factory where he receives preliminary instruction by specially qualified instructors. Supplementing the shop work each apprentice reports to the trades apprentice school four hours each week, two hours of instruction being devoted to blueprint reading and mechanical drawing, including tool design; and the remaining two hours divided between shop problems, economics, science, and manufacturing operations.

The National Metal Trades Association

This association also has an apprentice-training system which has been in operation for several years at different plants. It maintains an educational director who devotes his time to the study of apprentice training and shop instruction.

The Committee on Industrial Education of this Association says:

> Investigation in the metal-trades industry has shown that while in normal times there is a fair supply of semi-skilled specialists, there is always a dearth of skilled, all-around craftsmen. These highly skilled men are not only indispensable in the shop, but it is to this group that industry must look for its future foremen, superintendents and managers, and for practical designers and engineers.
>
> So pressing has this need become, that serious thought must be given to methods of adequate training of young men for this purpose if we would stimulate and not stifle the fullest development of American industry.
>
> Mindful of its urgency and realizing the consequences which must follow continued indifference toward this important question the National Metal Trades Association, after an exhaustive survey of the situation, has prepared a plan of apprentice training which, with slight modifications, will adapt itself to a shop of any size.

The association has adopted a standard form of indenture, setting forth in full and clearly all the details of compensation, service and training. Provision is made for a probationary period of three to six months, and by examination an apprentice who has had additional schooling may reduce the period of apprenticeship. Wages paid vary with the progress of the trainee, ranging from $33^1/_2$ per cent to 85 per cent of a journeyman's wages.

An interesting provision is made by which a highly specialized plant may send its apprentices to another plant for part of their training. This is a new type of "coöperative training;" in this manner they obtain the best instruction available in a group of industries.

Careful records are kept of each apprentice and his progress in learning each process. Each instructor grades each man on such qualities as speed, accuracy, etc., as well as on his skill on the particular process. The final record card shows the details of the four-year course, the time used, grade and instructors' estimate of personal qualities. The entire scheme is carefully planned and recognizes the rights and duties of the apprentice and of the company.

To a questionnaire sent out by the National Metal Trades Association, 572 replies were received. Of these 146 stated that some method of apprenticeship was being used, 72 train their operators, and 68 conduct foreman training classes. Of those training apprentices, 81 use the method of casual training by foremen, workmen, or by observation and practice, and 49 have definitely planned systems of instruction either in the production department or in an independently organized training division.

Shop Training

During the world war, various quick methods were adopted for training men for jobs with which they were more or less unfamiliar. Most of the methods had been used in industry for some years, but neither so extensively nor so intensively as in war work. Out of the experience of peace and war have come certain well-defined methods of training men for new jobs. These may be classed as:

1 Vestibule schools, where the training is in an independent organization and not in the production department.

2 The shop school conducted within the production department. This instruction may be by classes, by groups, or by special instruction for works clerks, routing clerks, and others of whom there are only a few in any plant even though it be large.

Vestibule Schools. There is no uniformity in the use of this term. It will be used here to define that type of training conducted in a separate shop where the trainees are segregated from those on production. Here it is proposed to give the "one best way" of doing a certain operation under good conditions. Learners are not distracted by the comments of other workmen. They do not learn the wrong way. They do not take the time of a foreman from production. They do not waste so much material.

On the other hand, a separate training department is not justified in the average small plant, but only where the demand for new, trained men is fairly constant and considerable. The separate school depends on the production department to absorb its output and if there is not close coöperation between the two, the separate school will be unsatisfactory.

The instruction often consists of one or two periods per day of classroom work and the remainder is spent on the process or operation to be learned.

The instructors should be chosen from the skilled men in the production department who have the ability to transmit what they know and tact in doing it. The production department will naturally object to losing one or more of its most valuable men for this purpose.

Shop Schools when conducted in the production department have the advantage of a certain elasticity. Instructors not required at the time can be put back on production. The majority of plants employ this method, and the foreman is most frequently the teacher. The modern demands on the foreman are much more severe and exacting than they used to be. To ask him to be a teacher also is a questionable expedient except where the number of trainees at one time is small. Where the plant expects foremen to be teachers, it seems reasonable to instruct them in methods of teaching.

The instruction is usually for the sole purpose of increasing the immediate productivity of new employees, saving waste of materials, and reducing wear and tear on machines. The training of apprentices is much broader and includes more of the industrial and economic background of production. The Federal Board for Vocational Education, in Bulletin No. 48, urges the importance of teaching in shop schools, the character of and sources of the materials used, the general processes of manufacture, the purpose and principles of planning and routing, the definition of terms frequently used, reading blueprints, job tickets, safety, welfare, hygiene, and the elimination of waste.

Wages During Training Period

In a plant where piece rates prevail a beginner will often become

discouraged and quit before he has learned the process and become sufficiently skilled to make a reasonable wage. It is usual to provide a special day rate during the period of training so that the trainee will be assured of a certain minimum income until he has the skill necessary to earn a higher wage on a piece-rate basis of payment.

Another method is to give the trainee a bonus, during the learning period, on the regular piece rate, depending on the production reached. If he does not accomplish the minimum production set he has the fixed day rate, and if he reaches or exceeds the minimum production he receives a bonus on the piece rate.

Where contracts are let to a group to construct or erect parts or the whole of a complicated machine, the cost of instructing a new man is sometimes borne by the group as a part of the total cost or contract price.

Where a group of workmen in a particular shop are held responsible for the instruction of new men, a leader is appointed who sees to the supply of tools, materials and the set-up of machines. The earnings of the leader may be charged to overhead, but enter into the cost of the job in that shop. In this manner the earnings of the group and of the individual are affected only by the time given by each man to instruction and not by the loss due to the reduced production of the leader.

A record card is kept of each learner, giving the time required to master each machine or process, the production output, and comments of the instructor or foreman on the progress of the learner. The time card also gives valuable information as to the capacity of different men to teach—or their indifference.

Difficulties in Shop Training

The old method of having the foreman "break in" the new men presumed some knowledge of the job by the employee and was in vogue when the foreman's job was much simpler than now. Because of this custom and the desire of some foremen to continue this duty, it is difficult to convince the management of the desirability of having trained teachers, i.e., men of skill who have been instructed how to teach. Too frequently a man is chosen to teach just because he knows the subject. Very often one who is not an expert becomes a better teacher because he has the gift or has been trained in the process of teaching.

Experience has demonstrated that assigning to the teaching an assistant foreman who has been trained to teach, or a selected workman who has the qualities of a teacher, is economy. In other words, the organization of teaching is important, and is increasingly important as the number of trainees increases.

Unfortunately there are very few books on teaching which are written for and adapted to this particular condition. However, a stimulus to the training of industrial teachers has been given by the Smith-Hughes Act—a federal law which provides funds with which to train industrial teachers for service in shops and in continuation and trade schools. Each state has an organization for this purpose operating under the joint supervision of the state department of education or public instruction and the Federal Board for Vocational Education.

The expense of maintaining trained instructors who are non-productive is frequently an objection in the eyes of the management. It is difficult to show by figures the reduced time and materials used in learning, the saving in wear and tear on machines, the saving in the foremen's time, the reduced turnover during the training period, the lessened interference with production, and the greater satisfaction to piece workers when they are not asked to break in new men.

Good instruction insists on doing the thing in the right way, and then learning to do it as fast as possible by correct methods. Production insists on doing the work as fast as possible, though the methods pursued may not be the best and ultimately may not lead to the greatest possible production commensurate with the effort made. There is a natural conflict between good instruction and the purposes of the production department which is not given due weight. It has been found that those who have received a thorough apprentice training often make good teachers because they have been thoroughly trained and have learned in the logical order, i.e., they have been given the simplest jobs first, then the more complex, while the desire to obtain early production may lead to an illogical order in the instruction of a new man and a waste of time.

Selection of Men

Another difficulty arises from the fact that in many plants there is little attempt to select men who are adapted to the job. An increasing number, especially of the larger plants, select both apprentices and skilled workmen (or those who are to be trained in some process requiring skill) with care. Educational tests of a simple character are given applicants for apprenticeships and systematic questions tending to establish fitness or unfitness are being applied to mature applicants. Trade and psychological tests were applied during the war and a valuable body of information and experience was gathered. There is much that is sound, and when turnover costs from one hundred dollars per man to twice that, it seems the part of wisdom and economy to apply discriminatory tests to all applicants, keep a simple record, and test the efficacy of such tests by experience. There are numerous sources of information on this subject such as the bulletin of the National Personnel Association, The Instructor, the Man and the Job, by Charles R. Allen,[1] and various journals on applied psychology, management, etc.

In conclusion, it is safe to say that whether the shop training should be done in a separate department or on the production floor depends on the size of the plant, normal turnover, complexity of the job to be learned, and other factors. In any case more attention should be given to organizing the instruction, selecting those to be trained with more discrimination, selecting instructors because of their skill as workers and as teachers, and so arranging the instruction as to give the new employee the best information available about his job, the methods, materials, and machines used. Some day we shall realize the importance of giving him a reflection of company ideals, methods of recognizing ability, faithful service, and loyalty. Perhaps industry will see the wisdom, even economy, of teaching its younger men the fundamental principles upon which a sound future industrial policy must rest. Up to the present time industry has had very few ideals, with marked individual exceptions, and such ideals as it may have had have been carefully locked in the safe rather than spread among the employees.

Industrial management in the United States, speaking broadly, has never used educational methods for its own salvation and for the upbuilding of industry. However, some have appreciated the value of teaching and have found such methods distinctly effective.

INDUSTRIAL EDUCATION AS REPRESENTED IN SCHOOLS

By C. R. RICHARDS,[2] NEW YORK, N. Y.

THIRTY years ago, the demand was often voiced on the part of employers for trade schools to train mechanics competently in place of the disappearing apprenticeship system. During these thirty years a number of attempts to meet this demand in schools both under private and public control have been made but the results and experience gained have not demonstrated that this function is one that can be served effectively in a large way by a school.

Outside of a number of schools run on a business basis for profit there are at present in the United States some fifteen or more schools that, strictly speaking, may be called trade schools, that is, schools admitting applicants sixteen years of age or over and aiming to train manual workers for a trade. The first of these, the New York Trade School, was founded by Richard T. Auchmuty in 1881. The development of schools aiming to take the place of apprenticeship in whole or in part after this date was very gradual—the Williamson Free School of Mechanical Trades was founded in 1889 and the Baron de Hirsch Trade School in 1891.

In 1907 the trade school entered upon the stage of public administration. In that year the Milwaukee School of Trades previously established was taken over by the city under the terms of the Industrial Education law passed by the Wisconsin legislature. Since that date public trade schools have been opened in Philadelphia, Pa., Portland, Ore., Bridgeport, New Britain and other places in

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[2] Director, Cooper Union. Mem. Am.Soc.M.E.

Connecticut, Worcester, Mass., Yonkers, N. Y., Indianapolis, Ind., and Scranton, Pa., together with several institutions on private foundations such as the David Ranken, Jr., School of Mechanical Trades at St. Louis, the Arthur Hill School of Trades at Saginaw, Mich., and certain departments of the Dunwoody Institute, Minn.

Certain of these schools—the New York Trade School and the Baron de Hirsch—represent the short-course type; the others offer courses of two or three years in which practical trade training is supplemented by instruction in drawing and technical practice and in some cases by science and mathematics.

One reason why schools of this type have not further increased in number is because of the severe economic difficulties under which they labor. First of these difficulties is the problem of support presented to the student worker during the period of instruction. Trade school training of the type under discussion is in common practice restricted to the period above sixteen years of age, and as the great bulk of the youth who will form the mechanical and industrial workers of the country must of necessity enter upon remunerative work at sixteen or shortly after, the sacrifices necessary to permit attendance at a trade school can be expected only from a comparative few. The second aspect of the economic problem in relation to such schools is found in the large expense of administration, instruction, materials, and physical maintenance in proportion to the number of students that can be instructed. To be successful the trade school must demonstrate not only that it can give a better training than that obtainable under practical commercial conditions but that it can give training so much better as to compensate for the loss of wages during the learning period. At the best it is only in a few high-grade trades, the full command of which involves extensive subject matter and breadth of experience, that trade-school training can claim sufficient advantages over training under commercial conditions to repay its expense. It is, consequently, only in cities representing exceptional concentration of such industries that trade schools, at least of the long-course type, can expect support, and it is not yet entirely clear even in these cases whether the results obtained are proportionate to their expense.

It is in other fields that the large place of the school as a factor in industrial training has become evident—in the fields of preparatory and supplementary education. Here the schools have demonstrated their great value.

To properly estimate the place of the school in this whole connection it is essential not only that some knowledge be had as to what is being done in schools at the present time, but that an understanding be developed as to what forms of instruction can be most effectively consummated outside of the industries—that is, in schools; and what phases can be developed effectively only inside the industries. Both types of training are essential in a comprehensive system of industrial education—one is complementary to the other—and both need to be encouraged with intelligent discrimination in order that they may be developed as parts of an effective whole.

Evening Schools

The largest development of supplementary instruction has been in the evening school. This type is the earliest development of industrial education in our country and today reaches the largest numbers. Cooper Union and Mechanics Institute of New York; Franklin Institute and Spring Garden Institute of Philadelphia; The Ohio Mechanics Institute of Cincinnati; and the Virginia Mechanics Institute of Richmond all opened their classes about the middle of the nineteenth century. These schools were all due to private initiative and it was only slowly that schools under public administration entered this field.

The early work of the evening industrial and technical classes consisted of various lines of drawing, to which were gradually added courses in science, mathematics and technical subjects. Beginning about 1890 certain of these institutions established practical shop courses in a few of the high-grade mechanical trades intended to broaden the experience obtained by the student during the day.

The concern of public evening schools was formerly almost entirely with general studies and it is only of late years that differentiated and specialized courses related to industrial practice have been introduced in the schools of the more important cities. The expansion of such work, however, is now going on rapidly. In New York State in the year 1920–21 there were enrolled 22,984 men and 4,222 women in evening industrial extension classes under public administration, admission to which required actual employment in a related trade. The law in this connection states:

> Evening vocational schools (may be established in cities) in which instruction shall be given in the trades and in industrial . . . . subjects which shall be open to pupils over sixteen years of age, who are regularly and lawfully employed during the day and which shall provide instruction in subjects related to the practical work carried on in such employment.

A list of the evening industrial courses for men given during the year 1921–22 in New York State is as follows:

- Auto mechanics
  - Auto-block testing
  - Chassis repairing
  - Engine repairing
  - Gas-engine theory
  - Lighting and starting
  - Storage batteries
  - Vulcanizing and tire repairing
- Architectural drafting
- Blacksmithing
- Book illustrating
- Clay modeling
- Commercial photography
- Cooking and catering
- Dental trade (mechanical dentistry)
- Electricity
  - Alternating-current theory
  - Direct-current theory
  - Electric installation (house wiring)
  - Plan reading and estimating for electricians
  - Principles of artificial lighting
  - Radio
  - Railway signal work
  - Telegraphy
  - Telephony
  - Underwriter rules and regulations
- Foreman training
- Hydraulics
- Industrial chemistry
- Interior decorating
- Jewelry design
- Life drawing
- Machine shop
  - Advanced machine-shop practice
  - Elementary machine-shop practice
  - Blueprint reading for machinists
  - Mechanical drawing for machinists
  - Free-hand sketching for machinists
  - Shop mathematics for machinists
  - Theory of materials and processes
  - Tool designing
  - Tool making
- Mechanical drafting
  - Advanced mechanical drafting
  - Elementary mechanical drafting
- Mill wrighting
- Motion-picture operating
- Mural designing
- Player-piano mechanics
- Plumbing and heating
  - Leadwork
  - Plan reading and estimating
  - Principles of heating and ventilation
  - Hot-air system
  - Hot-water system
  - Steam heating
- Poster designing
- Printing
  - Advance hand composition
  - Cost estimating
- Elementary hand composition
  - Job and cylinder presswork
  - Kelly press operating
  - Monotype operating
  - Offset presswork
  - Photo lithographing
  - Proof reading
  - Typographical design
- Sheet metal work
  - Plan reading and estimating
  - Sheet-metal drafting
- Shop mathematics
- Ship drafting
- Ship fitting
- Shoe finishing
  - Cobbling
- Sign painting
- Steam engineering
- Textiles
  - Garment-machine operating
  - Knitted fabrics
  - Lace designing
  - Loom repairing
  - Men's tailoring
  - Ribbon manufacturing
  - Textile chemistry
  - Textile design
  - Women's tailoring
- Woodworking
  - Advanced cabinet making
    - Elementary cabinet making
    - Drawing for cabinet makers
    - Blueprint reading for carpenters
  - Framing
    - Millwork
    - Inside finishing
    - Plan reading and estimating
    - Stair building
    - Use of steel square
    - Patternmaking
- Terra-cotta work
- Upholstering
- Welding
  - Electric
  - Oxyacetylene

The attendance in these trade extension courses in New York City during the year 1920–1921 was 13,538 men and 3,969 women.

Part-Time Classes

Part-time classes are a development of comparatively recent years. Laws making it permissive for municipalities to develop part-time classes in place of evening classes for employed boys and girls who had not finished the elementary school began to appear as early as thirty years ago. The first law making attendance compulsory in such classes was that of the state of Wisconsin in 1911.

This action was followed by other states until the number that have enacted such laws now reaches twenty-one. As long as these compulsory school laws referred only to boys and girls up to the age of 16 years they had limited significance from the standpoint of industrial education as the instruction given was necessarily largely of a general nature. In 1917 Wisconsin passed a law making attendance in a part-time school compulsory for all employed boys and girls up to 18 years of age. Since that time such laws have been passed in 10 states with the result that opportunities for imparting valuable instruction in matters related to the needs of the vocation in which the boy or girl is employed have developed. The opportunities for rounding out and broadening the education of the young workers in the industries thus presented are very important although the extent to which such instruction can function on the industrial side is largely dependent upon the size of the community in which such classes are maintained or upon a degree of industrial concentration in the community which will allow classes from single or related industries to be segregated so that specialized class instruction can be given.

The large opportunities for related vocational instruction in this field lie in connection with the high-grade trades involving considerable content of trade or technical knowledge depending on an understanding of elementary mathematics and science. In the case of low-grade factory industries where neither processes or materials present need for technical knowledge the school instruction must necessarily assume other directions.

The results of such instruction, however, whether dealing with pupils from skilled trades or factory industries, have been found of much assistance to foremen and superintendents in determining promotional opportunities inside the plant.

The numbers in part-time classes in New York state in the year 1921–1922 were 26,678 boys and 21,760 girls. The New York state law requires that part-time schools shall be established in cities and school districts having a population of five thousand or more inhabitants and that each minor under age of 18 years who is not in regular attendance upon some public, private or parochial school or who is regularly employed in some occupation, unless he has completed a four-year secondary course of instruction, shall attend a part-time school. Such attendance shall be for not less than four hours a week and not more than eight hours a week. These hours should be between the hours of 8 o'clock forenoon and 5 o'clock afternoon. This law was put in operation September, 1920, and municipalities are given until September, 1925, to put the law into full operation.

At the present time practically all cities outside of New York City require the attendance at such schools of all employed minors 14, 15, and 16 years of age. New York City requires the attendance of those 14, 15, and 16 years of age when they are not elementary school graduates. Schools or classes are now in operation in 103 communities in the state.

Part-time instruction is apparently destined to increase throughout our country until it reaches all employed youth up to 18 years of age. Under these conditions the study of just what elements of instruction can be given best in these classes is a matter of much importance and one requiring thoughtful consideration. The subject is receiving considerable attention and the elements of the problem have been very well analyzed in a bulletin recently put forth by the Federal Board for Vocational Education called "Part-Time Schools."

Vocational, Industrial, or Unit-Trade Schools

Preparatory industrial training or pre-employment trade training is represented in its most important phase by schools under public control called, variously, vocational schools, industrial schools, or unit-trade schools. These schools have arisen largely from the discovery of the fact first brought out by the report of the Massachusetts Committee on Industrial and Technical Education in 1906 that in the case of the large number of boys entering employment at 14 years of age, the two years following are largely wasted as far as progress toward a skilled trade is concerned.

The first school of this type to be established was at Rochester, N. Y., in 1908. Since then a considerable number of schools providing practical work in one or more of the large trade groups, together with related instruction in drawing, elementary science, history, English, shop calculations, accounting, and business forms have been organized in several eastern states. Such schools do not aim to impart a trade training but to develop some amount of industrial intelligence and knowledge of shop methods and materials in the boy or girl 14 or 15 years of age that they may be better prepared at 16 to enter upon industrial employment.

The causes that have brought the preparatory trade school into being in the United States are not alone the economic advantage to the industries in preparing better material for entrance therein, an advantage that employers would be quick to perceive yet slow to bring about; but rather the recognition on the part of the public of a social obligation to better the opportunities for great numbers of young persons to enter upon more substantial careers.

The development of these schools has been largely confined to the eastern Atlantic states, particularly Massachusetts, New York, New Jersey and Pennsylvania. In New York state there were twenty-four such schools in 1920–1921, scattered throughout the different cities of the state. There were five in New York City, four in Buffalo, three in Rochester and lesser numbers in the smaller cities. Table 1 gives the unit trade courses maintained in these schools and the enrollment for 1921–1922.

Table 1 Enrollment by Trade Courses in Unit Trade Schools of New York for 1921–1922

Name of Trade Course	Enrollment			Number of Schools Offering Courses
	Boys	Girls	Totals	
Electrical work	1636	0	1636	13
Machine shop	1299	0	1299	19
Auto repairing	1111	0	1111	8
Cabinetmaking-carpentry	689	0	689	15
Printing	477	0	477	12
Machine drafting	422	0	422	8
Patternmaking	304	0	304	9
Sheetmetal	226	0	226	8
Architectural drafting	159	0	159	2
Plumbing	146	0	146	4
Commercial design	115	0	115	2
Sign painting	72	0	72	1
Bookbinding	44	0	44	1
Painting and decorating	27	0	27	1
Forging	20	0	20	1
Industrial chemistry	16	0	16	1
Power-plant operating	16	0	16	1
Shoemaking	12	0	12	1
Dressmaking	0	1250	1250	1
Millinery	0	466	466	1
Garment-machine operating	0	190	190	1
Novelty, lamp shades, sample mounting	0	59	59	1
Garment design	0	29	29	1
Straw-machine operating	0	28	28	1
Flowers and feathers	0	27	27	1
Manicuring and shampooing	0	24	24	1
Embroidery-machine operating	0	18	18	1
Cooking	0	13	13	1
Totals	6791	2104	8895	

This type of school would appear to have become a stable element in the educational system and may be expected to assist materially in equipping a considerable number of boys and girls entering the industries with greater industrial intelligence, greater understanding of industrial processes, and greater interest in industrial careers.

Secondary Technical Institutes

A group of schools, small in number but performing most important work in mechanical and electrical fields, have been developed in various parts of the country in the last thirty years. These schools offer a technical training above that of the trade school and below that of the engineering school, aiming, in other words, to equip the technical expert, designer, inspector, tester, overseer, shop superintendent and power-plant superintendent, in short, the non-commissioned officers of industry. Prominent among these schools are Pratt Institute, certain departments of the Carnegie Institute, the Ohio Mechanics Institute, the Rochester Mechanics Institute, the Lewis Institute, the Wentworth Institute, and the Dunwoody Institute. Such schools comprehend courses in machine construction, electrical construction, industrial electricity, steam and electrical power-plant practice, foundry management and operation, machine design, industrial chemistry and courses called industrial mechanical engineering and industrial electrical engineering. The courses generally extend two years in length although in certain schools they carry beyond this time. It is to be hoped that this type of school will develop considerably further in our country. It has a task to perform purely its own and one of extreme value to industry and engineering.

Technical High Schools

A number of schools aiming to fulfil the office of secondary

technical schools have been organized under public administration in the last 20 years. The manual training schools which developed rapidly in the United States between 1880 and 1900 did not contribute, as they were expected, trained workers to the industries, and attempts have been made to convert some of these schools into technical high schools having the distinct purpose of preparing pupils for industrial leadership, that is, for positions in industrial life requiring skill and technical knowledge and of greater importance and responsibility than those of skilled mechanics. The weakness of such schools, considered from the standpoint of the productive or operating industries, lies mainly in the fact that they neither require practical experience before entrance nor provide parallel experience as in the case of coöperative schools. As a result their graduates have mainly entered drawing rooms and other white-shirt occupations in industry or else, to a considerable extent, gone on to engineering schools. One of the functions for which these schools seem relatively well fitted is that of preparing young persons for entrance into the field of industrial chemistry.

Cooperative Schools

The coöperative plan by which the students spend half their time at work in industrial establishments and half in school, and which was first highly developed in the engineering department of the University of Cincinnati, has since been applied to students of high-school grade. This plan differs from the part-time plan in some important respects. In the first place the student body consists of enrolled high-school students and not of young workers already employed in commercial establishments. In the second place the larger amount of time spent in school allows both general and technical education to be carried much further. This type of school is maintained in some 47 cities in our country at the present time but its exact place in the scheme of industrial education is not yet clearly defined. Whether, on the one hand, any considerable number of those aiming at and fitted for regular mechanics' work in trades will be drawn to such schools, or whether, on the other hand, such schools will develop capacity for training leaders of the foreman and expert type still remains to be seen.

It is to be doubted that many high school students can be counted upon to enter manual occupations in the industries. We must recognize that the ideals of the homes from which come the large body of high-school students are directed distinctly away from such occupations for the sons and daughters and it would seem clear that the contributions of the high school to the field of industry must be found in supplying young men with the basis of a good education who are fitted after a further period of practical experience to attain positions of at least subordinate leadership.

From this point of view it is evident that coöperative industrial classes in the high schools cannot be expected to reach large numbers, but on the other hand it is also evident that such classes give promise of developing a type of young man well fitted to find an important place in the industrial order.

Foreman Training

Considerable development has been made in the past two years in the very important field of foreman training. A valuable contribution was made to the subject by a report published in 1920 by the Federal Board for Vocational Education by Charles R. Allen.[1] The work has been forwarded both by the Federal Board and by state authorities. In the former case the work has been promoted in three principal ways:

First, by national conferences of four weeks in length held during the last two summers at Minneapolis, attended by state representatives and representatives of industrial concerns, in which courses for the training of conference leaders were developed.

Second, demonstration courses or conferences conducted by agents of industrial education service in industrial plants. A large number of these conferences have been held in various parts of the country in the last two years. The programs have almost uniformly covered a period of two weeks and foremen have been in attendance at the conference either five or six hours a day during working hours.

Third, through publishing the results of research and experimental work and distributing this material to persons in the states and industries who are concerned with the problem of foreman training.

Programs of foreman training have also been developed by the states of New York, Missouri, Pennsylvania, Nebraska, Virginia, Georgia, and Ohio. This work is generally conducted by some educational institution of recognized standing under the supervision of the special state agent in charge of this type of work. Most state work is conducted in industrial plants during the regular working hours.

The development of this work promises to be one of the most important as yet undertaken by the schools. It has been dealt with not on the conventional basis of school instruction but largely through conferences in which the chairman or leader seeks to make his points by drawing out the experiences of the foremen present. Assistance in this field has been eagerly sought for by employers and if the work is carried out with the same judgment and care that have marked its beginnings it may well prove of invaluable service to industry.

Results of Federal Vocational Education Act

The passage of the vocational education bill, commonly called the Smith-Hughes Act, by Congress in February, 1917, placed the the whole matter of vocational training in schools upon a new basis. By the provisions of this act, which went into effect July 1, 1917, one-half the cost of the salaries of teachers of trade and home economics subjects and of teachers and supervisors of trade and agricultural subjects is paid by the Federal Government up to the limit set by the government appropriation and one-half is paid by the state or local community. The state or local community or both must meet all the other expenses of the schools including site, plant, equipment and other expenses together with the salaries of teachers of academic subjects.

To take advantage of its provisions the act requires the state through its authority to accept the provisions of the federal bill, designate or create a state board of control and designate the state treasurer as custodian of the funds. All moneys disbursed by the board are paid by the state treasurer to approved schools as reimbursement for expenditures already incurrred. Federal money is paid to local communities only after their work has been approved by the state board on the basis of the federal act.

Schools entitled to the benefit of the federal grant are: (*a*) all day schools in which half the time must be given to actual practice of a vocation on a useful or productive basis; (*b*) part-time schools or classes for workers over fourteen years of age; (*c*) evening schools or classes for workers over sixteen years of age.

In order that states may receive federal aid, teachers, supervisors, and directors must have the minimum qualifications, the plant and equipment must meet the minimum requirements, and efficiency of instruction must meet the minimum standards as set up by the state board and approved by the federal board.

The Federal Board for Vocational Education is composed of the Secretary of Agriculture, the Secretary of Commerce, the Secretary of Labor, the United States Commissioner of Education and three citizens appointed by the President by and with the consent of the Senate, one to be a representative of manufacturing and commercial interests, one a representative of agricultural interests, and one a representative of labor.

The effect of the Federal Vocational Education Act upon the development of vocational education since its enactment has been very marked. Prior to the passage of the act only seven states in the union had enacted laws recognizing vocational education as a part of the public school program and appropriated funds to assist local communities in developing this type of work. Before January 1, 1918, every state in the union, through official action by the legislature or by the governor, had accepted the provisions of the Federal Vocational Education Act. Every state during the same period submitted plans for accepting the provisions of the federal act and the rulings of the Federal Board for Vocational Education as regards standards and methods. Every state also set up a definite State Board for Vocational Education and organized itself for the discharge of its duties under a responsible staff. The number of states employing supervisors of trade and industrial education in 1916 was seven, in 1921 was forty-five.

[1] Staff Federal Board for Vocational Education, Washington, D. C.

In 1916 the total appropriations by states for vocational education was $1,300,510.15 and expenditures by local communities was $2,118,208.96, making a total of $3,418,719.11. In 1921 the total state appropriations were $5,595,956.78, those by local communities $9,489,809.01, and federal appropriations in the same year were $2,949,850.57, making a total of $18,035,616.36. The most significant element in these figures is the increase of local appropriations largely brought about by the stimulus of federal grants. Enrollment in federally aided vocational schools increased from 164,186 in 1917 to 323,028 in 1921.

The publications prepared by the Federal Board for Vocational Education upon various problems of vocational education and administration have been extremely helpful to those engaged in the field.

The value represented by the great expansion of vocational education under public control undoubtedly should not be entirely measured by figures of enrollment or by money expended. During the rapid development of the last few years, some of this work unquestionably has not been entirely effective or well done, as it has not always had the benefit of thoroughly competent instructors or supervisors. Like other educational work under public control its character is largely dependent upon the quality of personnel that is represented in the state departments of administration and by the local supervisory officers. It would seem to be a fact, however, that in most of the states the men occupying these positons represent a new type of educator, a type practically minded, generally possessed of some measure of practical experience and characterized by energy, initiative, and forward-looking vision.

Machinery has been set up and a large personnel developed for a vastly important work and if the results of this work, the policies pursued, and the quality of organization represented can receive both criticism when deserved and encouragement when merited from practical men and in particular from men of engineering status, the possibilities of sound and competent development of this phase of industrial education will be greatly increased.

The foregoing review of the present status of the many types of industrial education proves that such education has already advanced in a truly remarkable way and promises much for the future. An attendance in trade extension courses in New York alone of over 100,000, with approximately 325,000 studying in federally aided vocational schools supported by appropriations of over $18,000,000, together with a record of over 4,000,000 students in the United States having completed correspondence courses, will suggest much to the lay mind.

Director Moyer gives a clear and valuable survey of existing facilities for correspondence instruction and shows how employees of the industries may best secure the advantages thereof. That these advantages may be the greatest, each industry should coöperate with the university-extension agency in its state and secure for its employees the additional personal instruction furnished when correspondence instruction is applied for by groups, and the consequent formation of what are called extension classes.

Dean Sackett's description of existing apprentice and shop schools will prove of value to every industry which has under consideration the starting of such a school in its own establishments. The associated analysis by Dean Sackett of the difficulties to be overcome is not the least important part of his contribution.

Director Richards deals with the organized trade schools and vocational education of industrial nature in the public schools. Evening schools, part-time schools, unit trade schools, secondary schools and high schools for technical training, and coöperative schools of vocational nature are all included within his theme aud receive his illuminating analysis. A very important part of the paper is his summary of the results of the Federal Vocational Education Act.

The Committee is of the opinion that not only are these papers which it puts forward as its report of much value in themselves, but that a full discussion of the subjects treated therein by the members of this Society who are directly connected with manufacturing will result in an additional improvement in the practice.

W. W. Nichols, *Chairman,*
Committee on Education and Training for the Industries.

Discussion

The previous reports were presented at the A.S.M.E. Annual Meeting Session held December 5, 1922, with W. W. Nichols, Chairman of the Committee on Education and Training for the Industries, in the chair.

In discussing the section devoted to extension and correspondence schools, Dane A. Carpenter pointed out that, while instruction by correspondence is as old as written language, the large field for this work is evident from the fact that only 13.9 per cent of the pupils entering grammar school graduate from high school and only 2.3 per cent graduate from colleges or universities. Even though colleges increase their registration at the present rate they will be able to handle only a small fraction of the high-school graduates. Mr. Carpenter expressed the belief that the disadvantage commonly mentioned in connection with correspondence teaching, namely, lack of personal intercourse between teacher and pupil, and pupils in schools, had been greatly overstressed. He emphasized the fact that the merit of any correspondence institution depends upon inspirational effort, adequate textbooks, and educational service. He agreed thoroughly with Dr. Hollis, who, in his introduction to Dr. Moyer's paper, stated that the strength of the correspondence school was its ability to employ the very best talent in the preparation of the textbooks. D. B. Preston told of the work being carried on by the Extension Division of the United Y.M.C.A. schools. The standard course which is being carried on by the Y.M.C.A. schools in class rooms of various manufacturing institutions throughout the country is also being conducted by the Extension Division by correspondence. The Executive Division instructors who direct the lessons and check and compare results have found that in almost every case the work of the Extension Schools is superior to that of the class-room students.

In closing his discussion, Dr. Moyer stated his belief that our high-school education should be changed so that the students would be encouraged to take a smaller part of the high-school work and finish their education by night-school study, in extension schools, or by correspondence schools.

In his discussion on the second subdivision of the report, that devoted to school for apprentices and shop training, George M. Basford stressed the importance of convincing the higher executives of the organization that men can be trained and can be used after training. Only when executives look inside their own organization for the man they want and for the man they themselves have made, can training in the industries and by the industries be successful.

J. C. Wright emphasized the words of the previous speaker and assigned to the engineers of the country the responsibility for leadership in securing a greater understanding of the need for industrial training. He asked for the moral support and active assistance of the engineering profession for the Federal Board for Vocational Education. Frank B. Gilbreth also supported the remarks of Mr. Basford as to the importance of securing understanding by executives of the need for industrial training, especially that type which recorded "the one best way."

J. P. Brown, F. P. Anderson, James A. Moyer, W. H. Sawtell, and F. E. Matthewson discussed the merits of the high school and its place in preparing for industry. In closing the discussion Dean Sackett reëmphasized the marked change in the attitude of management toward education as exemplified by the period preceding the war in comparison with the war period and since the war. He stated it was his belief that one of the best contributions of shop training is the bringing together of the management and the men into closer relationship, and if this relationship permits the discussion of the fundamental principles of sound industry, a great deal has been accomplished. Arthur L. Williston stressed the importance of grouping in the preparation and training of the workers of industry. He suggested that each member of the Society attempt to induce the organization with which he is connected to record the facts regarding the extent to which workers were devoting themselves to self-improvement in correspondence schools or part-time schools. Dr. Hollis stated that all education must tend toward fitting young men to make a living that they might not become public charges and to use intelligently the spare time that they can gain by reduction of hours of labor.

New Factors Influencing the Design of Woodworking Machinery

By SERN MADSEN,[1] CLINTON, IOWA

Such factors as the adoption of high-speed steel, demands of greater economy, power and speed, the use of ball bearings, and the direct application of the electric drive, necessitate new standards for woodworking machinery. The author discusses these factors, summarizes the problems of driving and fitting cutter heads, and tells how ball bearings and electric motors overcome many of them. The savings in power resulting from the use of ball-bearing motor-driven arbors are pointed out, and the paper includes tables of synchronous-motor speeds and motor speeds available with two and three frequencies.

WOODWORKING machinery, which has been considered standard for many years, is now passing through a period of revolutionary design. Among the many factors which are causing this change may be mentioned: (1) Adoption of high-speed steel and improved cutter-head design; (2) the demands for greater speed and more economical production; (3) the use of ball bearings for high-speed arbors; and (4) the direct application of the electric drive, first to individual machines, and now to each individual head.

It is the purpose of this paper to show how these factors are greatly influencing and determining the type of woodworking machinery of the future. The machines considered, for the most part, will be those used in the sash, door, and millwork industries,

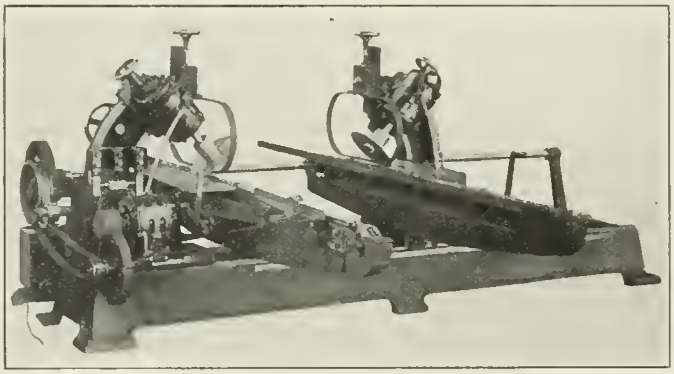


Fig. 1 Double Cut-Off Saw

(The motor applications to this machine illustrate how well motors can be used to apply power to arbors adjustable to various angles. These motors are built to carry the entire bearing load in the end plates of the motor itself. The bearings are of the single-row deep-groove type with about 18 or 20 $^5/_{16}$-in. balls. Grease lubrication is used.)

and these represent quite completely all the machinery used in the remanufacture of lumber into finished products.

Practically all woodworking machines perform their work by a process of milling, abrading, boring, or pressing. By far the greater number perform shaping operations and use milling or cutter heads of various shapes and forms. Discussion of this class of machines, alone will be fairly representative of the entire line.

Cutter Heads

In the early days of the development of the woodworking industry only the very choicest lumber was used. Preferably softer woods and the straighter-grained materials went into articles requiring much shaping and fine finishes. With such materials the old-style square cutter head did remarkably well. Having a hook with an angle of 45 deg. it cut and planed well with a minimum of power required. The growing scarcity of softer wood resulted in the necessity of working up not only the harder woods but the crooked-grained materials as well. Coupled with this came the demands for greater speed. The square head, though still used to some extent, had a tendency to tear due to its great hook. The remedy was to back bevel or reduce the cutting angle of the bits. Two difficulties were encountered: carbon steel would not stand up, and the power required to drive the heads increased. The adoption of high-speed steel remedied the one difficulty but did not reduce the power.

The improved work and absence of tearing resulting from more of a scraping cut has so influenced cutter-head design that now it is not unusual to find cutter heads with as little as 5 or 10 deg. rake instead of the original 45 deg. With cutters having so little angle the shavings are broken up and come off more curly. In some cases the power required may be reduced by setting the cutters at a sufficient angle to produce a side-shearing cut.

More Power and Speed

When it was found that high-speed steel would stand the scraping cut it became almost universal practice to apply more power and turn out more work. Milled-to-pattern bits and round heads with their high-speed-steel bits were developed; as all of these could withstand greater centrifugal stress, higher speeds could be used in an endeavor to obtain more knife cuts.

Here again it was found that more power and more speed meant wider belts, larger pulleys, and excessive belt speeds. At somewhere around 4000 r.p.m. we begin to experience more or less trouble in transmitting power to the cutter heads by means of belts. Centrifugal force tends to reduce both the grip of the belt and the arc of contact on the cutter-arbor pulley. The high belt speed tends to whip it to pieces and necessity for greater tension strains the belt. Heating up of the pulleys tends to increase belt slippage and further aggravates the trouble.

Whether influenced by these considerations or not, belt-driven machines have not generally been designed to operate at more than from 3600 to 4000 r.p.m. The use of two driving belts, one at each end of the cutter-head arbor, has enabled some machines to operate at the higher speeds.

Since designers were limited in the direction of increased cutter-head speeds and since it is practically impossible to set two or more knives or bits to cut exactly the same, it was necessary to find some means of securing a greater number of uniform-depth knife cuts per revolution of the cutter heads. Larger-diameter cutter heads were adopted and more bits inserted, but no matter how carefully set up, generally but one bit actually does the finish cutting and leaves "revolution marks" on the work. The axis of rotation of a cutter head at high or operating speed is never the same as at rest. Slight unbalance causes a corresponding "throw" at high speed which may be sufficient to cause one bit to cut deeper than the rest. We may be able to make all bits cut, but seldom will they "finish" the same depth. A difference of 0.001 in. or less is very apparent on feeds greater than 1 in. for each 15 revolutions of the cutter head.

The problem of getting all bits to cut has practically been solved by jointing or dressing them to even length with a stone while the head runs at cutting speed. High-speed steel is much more satisfactory where jointing is necessary. If the "heel" produced by jointing varies too much on the successive bits or cutters the effect is as bad as though one were longer than the others. In spite of all these improvements there are still cutter heads that cannot be jointed and we must depend on higher rotative speeds.

Having summed up the various problems of driving and fitting cutter heads, it is interesting to note how admirably ball bearings and electric motors overcome many of them. The belt drive, at its best, subjects the bearings to more or less pounding and vibration and also causes a tremendous amount of side pull and friction owing to belt tension.

A motor direct-coupled to the arbor overcomes some of these

[1] Superintendent of plant equipment, Curtis Companies, Inc. Mem. Am.Soc.M.E.

Contributed by the Forest Products Division and presented at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. Slightly abridged. All papers are subject to revision.

objections, but still involves difficulties with couplings, alignment, etc., besides requiring considerable space.

A practice which is constantly growing in favor is to "build the motor in" so as to make the motor shaft and cutter arbor identical. While such an arrangement is ideal in providing high speeds, even, steady torque, and an abundance of power, it still involves some problems in bearing design. On this one point there is still no approach toward standard construction. Some machine builders mount the motor entirely outside the main arbor bearings and let the rotor run on an overhung shaft with no bearings in the stator whatsoever. This construction works very well on lower speeds up to possibly 1800 r.p.m., but its use is questionable on speeds of 3600 r.p.m. and higher.

Attempts have been made to improve this construction by use of an outer bearing in the motor, but best practice greatly favors the use of only two bearings on any high-speed arbor wherever possible.

Another method which appears to meet with more approval is to build the motor frames exceedingly strong, with heavy bearings and as great overall length as practical.

One machine builder has adopted a construction involving a heavy yoke with heavy bearings at each end and mounting the stator on the yoke. While this is an exceedingly heavy construction, it does remove nearly all mechanical stress from the motor frame itself.

Still another method of construction used by a prominent machine builder consists of mounting the arbor in the usual bearings at the ends of a heavy yoke. The motor complete is located on the arbor between these bearings, and ball bearings in the end plates maintain clearance between rotor and stator.

These varied types of construction show that no definite best plan has yet been decided upon. The essential problem is to provide for:

1 Rigid bearings without end play for the cutter-head arbor
2 Bearings that will maintain, or are adjustable for, clearance between stator and rotor
3 Bearings that will stand up at the higher speeds of 5000 to 7000 r.p.m.

Ball Bearings

In nearly all of the designs ball bearings are used and are meeting with very good results. Types of bearings vary from the double-row self-aligning type to the deep-groove single-row. The latter has the preference where end play is to be prevented, but the former is much preferred where radial load is predominant. It is quite important that end thrust be cared for at only one bearing and that all other bearings be free to move longitudinally with the shaft as it may expand or contract. One manufacturer uses a well-lubricated bronze thrust bearing to resist end play in one direction, while one of the ball bearings meets it in the opposite direction.

In the usual construction the inner ball race is locked to the arbor while the outer race is free to creep or turn gradually. Bearing manufacturers claim this is desirable in order to distribute gradually the wear to different surfaces of the outer race. Instances are known, however, where this has gradually worn the retaining case to the point of objectionable looseness. Proper lubrication also seems, to be a problem worthy of further study. Ordinarily hard-grease cups are used but better, more nearly fool-proof devices, are needed. Automatic circulating-oil lubrication seems most desirable for high speeds. Prevention of oil leakage into the motor windings is a difficult problem to solve successfully.

The life of ball bearings at high speed is something not yet well determined. It is generally agreed that they do not need replacing so often as babbitted bearings. Very few properly designed bearings fail short of what is considered satisfactory service.

Even with the possibility of an occasional bearing failure, there nevertheless seems to be a general feeling among users that it is far cheaper, both in time and money, to replace an occasional ball bearing, than to replace babbitted bearings giving a like service. A prominent designer advances the belief that the average life of bearings operating at 3000 to 7200 r.p.m. will be about three years, and that at speeds slower than this they will last indefinitely.

Power Requirements

The savings in power resulting from the use of ball-bearing motor-driven arbors is little short of amazing. Tests of motorized and belt-driven equipment seem to indicate that we may hope to save nearly 50 per cent of the power now used for driving such machines as molders, stickers, planers, sanders, etc. This is cheering news in the face of the facts brought out earlier in this paper that the later types of heads designed to do better work do require more power to drive them. By this happy coincidence it may be possible for woodworking plants to keep their power requirements from continually mounting higher.

While it is encouraging to know that the total power requirements of a woodworking plant can be reduced by the substitution of ball-bearing motor-driven machinery, there nevertheless are other new problems that must be considered. In order to motorize a machine completely it is necessary to make the aggregate horsepower of all the individual motors much greater than the average power consumption of the machine. Each motor must be enough oversize to care for extreme or overload conditions. Oversize or underloaded motors operate at a lower power factor. It is therefore necessary to provide either oversize generators or to install syn-

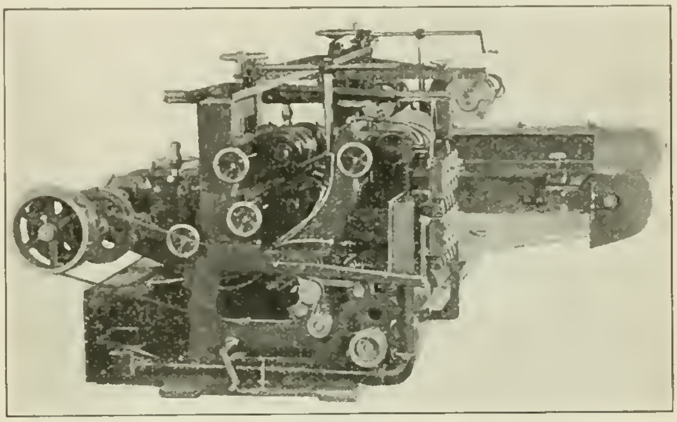


Fig. 2 Double-End Cut-Off Saw

(This machine uses nine motors and illustrates well how belt and gear drives are being eliminated. To meet the limitations of small space even the motors have to be built with small diameters and increased in length. Motor controls on this class of machines provide that the motor driving the feed will stop automatically if for any reason any one of the cutter-head motors should stop. Push-button control is being adopted almost exclusively.)

chronous condensers. In a new layout perhaps the larger generator is preferable, while for equipment already installed the synchronous motor offers the best solution.

Higher Frequencies

In general, 3-phase 60-cycle current is standard for woodworking plants. This limits motor speeds not only to 3600 r.p.m. maximum but also to comparatively few other speeds. Frequency changers are now standard equipment with many electrical manufacturers, and they are generally installed as individual units to care for each new high-speed motor-driven machine as installed. This practice soon requires an undesirable number of extra units.

A problem which is already becoming acute is to determine the better practice of providing higher-frequency current, whether by frequency changers or by direct generation in the power plant; also how many frequencies should be available and which will give the most desirable range of motor speeds. Table 1 gives the available synchronous speeds for a wide range of frequencies. From this we can choose such combinations as are desired.

Assuming that 60 cycles will always be standard and that one other frequency is desired, Table 2 gives the additional motor speeds for 80 and 85 cycles. Of the two, 80 cycles gives the better range, but the maximum speed available may not be considered high enough. If the highest speed must govern, then 85 cycles is preferable.

If we wish to have three frequencies available we find that 60, 75, and 90 cycles or 60, 80, and 100 cycles give the best ranges of speeds with the most uniform steps. The combination shown in the left-hand half of Table 3 gives a most desirable range above 1080 r.p.m. and is probably preferable for direct connection of motor to cutter head arbors.

The right-hand half of Table 3 shows a combination of speeds that has fairly even steps all through and is especially even in steps

TABLE 1 SYNCHRONOUS MOTOR SPEEDS

No. of Poles	Number of Cycles 60	65	70	75	80	85	90	95	100	105	110	115	120
2	3600	3900	4200	4500	4800	5100	5400	5700	6000	6300	6600	6900	7200
4	1800	1950	2100	2250	2400	2550	2700	2850	3000	3150	3300	3450	3600
6	1200	1300	1400	1500	1600	1700	1800	1900	2000	2100	2200	2300	2400
8	900	975	1050	1125	1200	1275	1350	1425	1500	1575	1650	1725	1800
10	720	780	840	900	960	1020	1080	1140	1200	1260	1320	1380	1440
12	600	650	700	750	800	850	900	950	1000	1050	1100	1150	1200
14	512	555	597	640	683	725	768	811	853	896	939	981	1024
16	450	487	525	562	600	637	675	712	750	787	825	862	900

TABLE 2 MOTOR SPEEDS AVAILABLE WITH TWO FREQUENCIES
(2- to 16-pole motors)

Cycles 60	80	Difference in speeds
450		
		62
512		
		88
600	600	
		83
	683	
		37
720		
		80
	800	
		100
900		
		60
	960	
		240
1200	1200	
		400
	1600	
		200
1800		
		600
	2400	
		1200
3600		
		1200
	4800	

Cycles 60	85	Difference in speeds
450		
		62
512		
		82
600		
		37
	637	
		83
720		
		5
	725	
		125
	850	
		75
900		
		120
	1020	
		80
1200		
		75
	1275	
		425
	1700	
		100
1800		
		750
	2550	
		1050
3600		
		1500
	5100	

TABLE 3 MOTOR SPEEDS AVAILABLE WITH THREE FREQUENCIES
(2- to 16-pole motors)

Cycles 60	75	90	Speed Diff.
450			
			62
512			
			50
	562		
			38
600			
			40
	640		
			35
		675	
			45
720			
			30
	750		
			18
		768	
			132
900	900	900	
			180
		1080	
			45
	1125		
			75
1200			
			150
		1350	
			150
	1500		
			300
1800		1800	
			450
	2250		
			450
		2700	
			900
3600			
			900
	4500		
			900
		5400	

Cycles 60	80	100	Speed Diff.
450			
			62
512			
			88
600	600		
			83
	683		
			37
720			
			30
		750	
			50
	800		
			53
		853	
			47
900			
			60
	960		
			40
		1000	
			200
1200	1200	1200	
			300
		1500	
			100
	1600		
			200
1800			
			200
		2000	
			400
	2400		
			600
		3000	
			600
3600			
			1200
	4800		
			1200
		6000	

for speeds below 1000 r.p.m. This makes this combination especially desirable for direct connection of motors to exhauster fans where quite definite speeds are needed and which are not obtainable with the 60-cycle current alone. Everything considered, 60, 80, and 100-cycle currents seem to be the most desirable. This permits a start with 60 and 80 cycles as in Table 2 and later adding the 100-cycle current.

Another use of two or three frequencies for is driving feed motors. It also makes available a proper cutter-head speed to suit the work being done, a practice which is still quite unknown to the woodworking industry. One machine-building company already cares for this by using a multi-speed motor for driving the frequency changer, which indicates that variable cutter-head speeds may even now be on the way. It seems logical that different woods and different cutter heads should operate at different speeds for best results.

Power Generation

There are many ways of generating or converting power of different frequencies, such as:

1 Main generator, 60-cycle; others through frequency changes

2 Two or more independent units operating at different frequencies

3 One large prime mover with two or three generators on the same shaft.

In small plants the first method is undoubtedly to be preferred. Where only two frequencies are desired two separate units might be preferable, especially for larger plants. When three frequencies are desired it seems best to use at least two units and possibly to put two generators on one shaft.

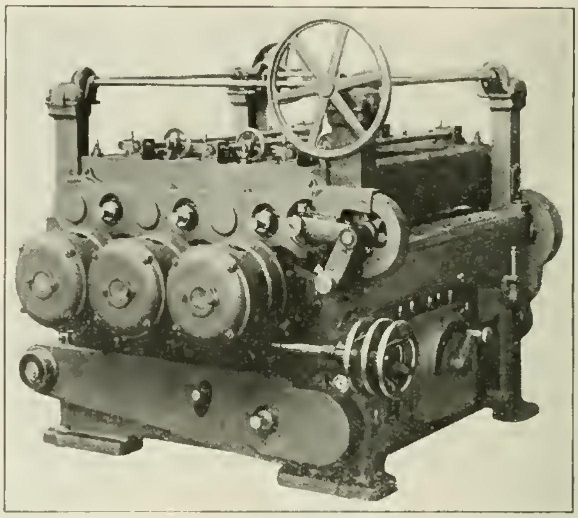


Fig. 3 Three-Drum Direct Motor-Driven Sander with Overhung Motor

(This design illustrates perhaps one of the most successful designs of motor application in which the motor is overhung. The stator is attached securely to a yoke which connects to two drum bearings, while the rotor is mounted directly on the projecting end of the drum shaft. This construction insures perfect alignment at all times, since all parts move as a unit. End oscillation of the drum is provided for by use of a rotor of slightly greater length. The usual drum speed, 1200 to 1800 r.p.m., is low enough to permit use of the overhung motor without an outside bearing.)

Another solution may be in specially built generators with multiple windings. These are problems that are worthy of some thought. Each plant will have its own problems as to how large the capacity for current of each frequency must be. It would be desirable to have the higher frequency units arranged to operate at 60 cycles in emergencies. Nearly all woodworking machines can be operated with considerable variation in speed if necessary, in case of breakdown or emergency. Other considerations will be extra switchboards and power lines, but this part of the multiple system is not complicated.

This discussion has thus far dealt but briefly with these new factors in woodworking-machinery design, but it is hoped that it may point out the opportunity for standardization among machine builders in getting out this new line of electric machines. Among the items that may well be standardized may be mentioned the following:

1 Use of 3-phase 60-cycle 220-volt alternating current as the basic standard for power in woodworking plants

2 Adoption of either 40- or 50-deg. rating for motors; 40-deg. motors are decidedly to be preferred in woodworking plants

3 A definite choice of certain higher frequencies. The adoption of 60, 80 and 100 cycles is suggested

4 An attempt at standard design for motor mounting, arbor bearings, and motor-control apparatus.

The reason for such standardization is to simplify the amount of apparatus with which the woodworking-machine operators must be familiar. Simplicity and standardization will be greatly appreciated by the users and will contribute greatly to the development of this type of machinery.

Pulverized-Coal-Burning Central Station, Bruay Mines, France

By JACQUES BOYER

DESCRIPTION of an installation said to be one of the largest pulverized-coal-burning plants in Europe and which embodies several improvements as compared with general European practice.

Fig. 1 shows the pulverizing plant with a capacity of 180 tons of coal per day of 16 hr. It comprises two concrete coal bins located under a standard-gage track and intended to receive from the cars the coal as it comes from the mines. Two belt conveyors with a capacity of 25 tons per hour deliver the coal from these bins to two elevators which lift it to another bin over the grate of a rotating drying furnace. (This drying furnace is shown in the original article by a halftone not suitable for reproduction.) After drying, the coal passes through a magnetic separator which removes any particles of iron it may contain, and then is carried by two elevators to a screw conveyor (Fig. 2) which distributes it among three hoppers. From these it flows by gravity into three Simon-Carves ball crushers. The pulverized coal is then lifted by air suction and delivered by a blower into two storage bins, whence it can be fed by gravity as desired on to weighing platforms so as to check the amount employed each day by each furnace. From the weighing platform the coal is delivered to the proper furnaces by piping with an inside diameter of 100 mm. (3.9 in.).

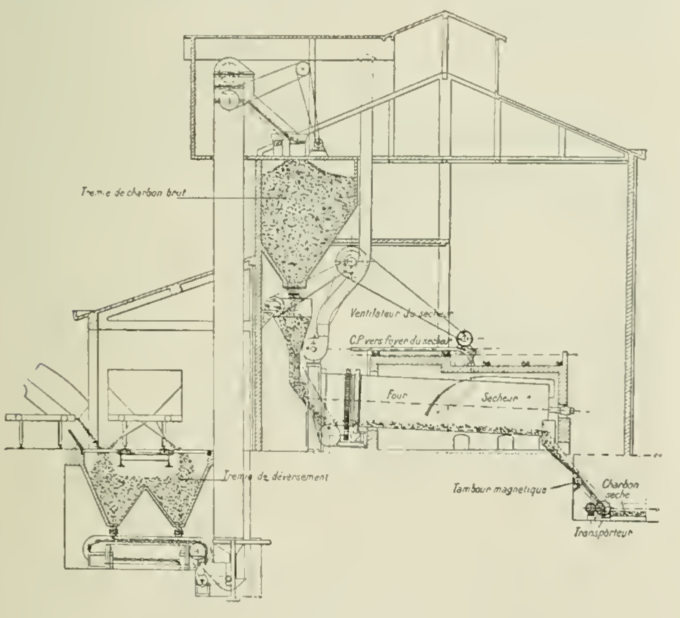


Fig. 1 Diagrammatic View of the Pulverizing Plant at the Bruay Central Station

(*Trémie de charbon brut* = raw-coal bin; *trémie de déversement* = discharge bin; *ventilateur du sécheur* = drier blower; *C.P. vers foyer du sécheur* = conveyor belt delivering pulverized coal to the drier furnace; *four sécheur* = drier furnace; *tambour magnétique* = magnetic separator; *charbon séché transporteur* = dry-coal conveyor.)

As has been shown by Michel Sohm, chief engineer of the surface plant of the Bruay mines, the condition of the pulverized coal has an important bearing on its combustion. In order to carry the degree of fineness to which the coal is broken up as far as possible the crusher is equipped with a horizontal shaft provided with four sets of articulated handlike members working as hammers. This machine pulverizes coal in sizes 0.10 to 0.15 mm. (0.0039 to 0.0059 in.) both by friction and by percussion.

Furthermore, the dimensions of the combustion chamber of the furnace must be properly proportioned for a given fineness of coal. As a matter of fact it is easy to see that coarsely granulated coal will require a greater excess of air than an impalpable coal powder. Likewise, the length of time that the powder has to remain in the furnace in order to achieve complete combustion also depends on the size of its grains. Thus slaty coals, which are the hardest to pulverize, come out from the machine with a coarser grain and their velocity of ignition is clearly inferior to that of pure coal; they ignite at a greater distance from the tip of the burner, soften, and

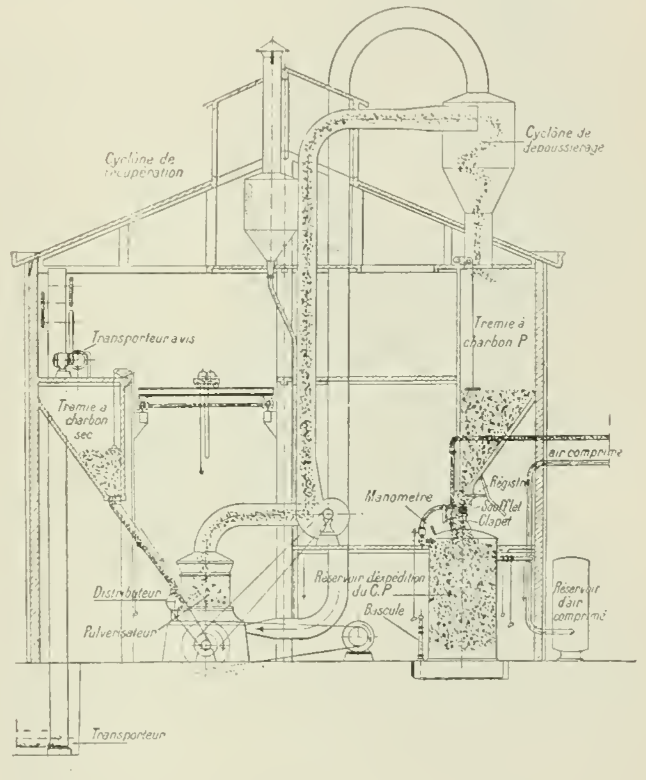


Fig. 2 Diagrammatic View of the Plant for the Storage and Delivery of Pulverized Coal to the Furnaces

(*Cylone de récupération* = recuperator blower; *cylone de depoussiérage* = dust-elimination blower; *transporteur a vis* = screw conveyor; *tremie à charbon sec.* = dry-coal bin; *tremie a charbon P.* = pulverized-coal bin; *air comprimé* = compressed air; *régistre* = damper; *soufflet* = bellows; *clapet* = valve; *réservoir d'air comprimé* = compressed-air reservoir; *réservoir d'expédition du C.P.* = delivery bin of pulverized coal; *bascule* = weighing bridge; *distributeur* = distributor; *pulvérisarteur* = pulverizer; *transporteur* = conveyor; *manométre* = manometer.)

clinker whenever the grains come in contact with each other, and in order to insure their complete combustion it becomes necessary to provide longer paths for their travel.

The above considerations explain why it is that as the hammers of the crushers wear away, the walls of the combustion chamber, the bottom parts of the lower passages, and the orifice of the injector become covered with slag. The reason is that unless the crusher hammers are renewed from time to time, the degree of fineness, which was fully efficient initially, ceases to be capable of providing for complete combustion. Moreover, variations in the degree of humidity have a notable influence on the output of the pulverizing equipment and on the regularity of flow of the pulverized coal either at its exit from the storage bin or through the distributor passages or burners. Hence the necessity of preliminary drying, which makes it possible to use all kinds of coal.

At the Bruay central station (Fig. 3) only dry coal ground to an impalpable powder is used. This coal is delivered by distributor fans into bins located in front of the furnaces. At the bottoms of these bins there are two controllers per boiler which distribute the fuel to the furnaces, while a low-pressure blower supplies each furnace with the air necessary for combustion. The air is mixed with the coal just before they enter the furnace. Various precautions have been taken to prevent the penetration of the pulverized coal into the crusher or engine rooms. It is said that these precautions have been of such a nature that the total loss in weight of coal from the time it is discharged from the cars to the time it is delivered to the furnace is less than 0.6 per cent. The controller distributors of the pulverized coal are equipped with a simple regulating device involving the use of a flywheel driven by a variable-speed motor, and this insures a regular supply of fuel to the furnaces.

As shown in Fig. 3, each furnace consists of a combustion chamber,

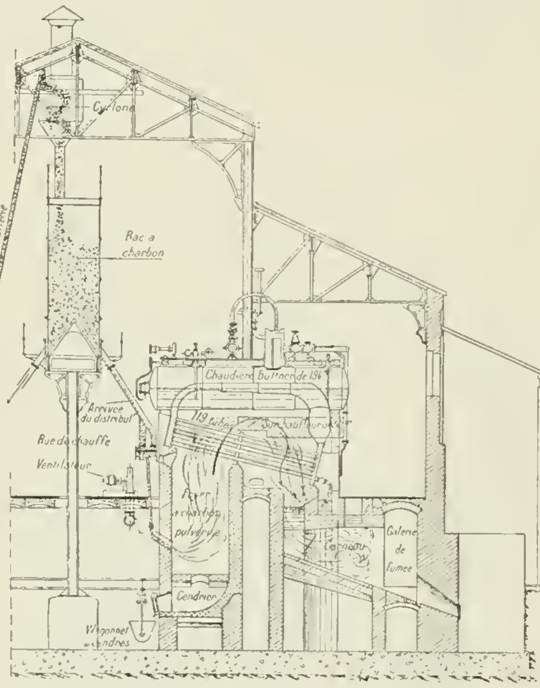


Fig. 3 Diagrammatic View of the Buttner Boiler Equipped for Burning Pulverized Coal

(*Cyclone* = fan; *transport de C.P. vers chaufferie* = conveyor delivering pulverized coal to furnace; *bac à charbon* = coal bin; *ventilateur* = blower; *arrivée du distribut* = distributor delivery line; *chaudière Buttner de 194m²* = Buttner boiler with 194 sq.m. heating surface; *surchauffeur de 50m²* = superheater with 50 sq.m. heating surface; *carneau* = flue; *foyer a charbon pulvérisé* = pulverized-coal furnace; *cendrier* = ashpit; *wagonnet a cendres* = ash car.)

separated by an arch from the slag pit, which latter is provided with a door that closes automatically. This arrangement facilitates the flow of the powdery or molten slags and also makes it possible for them to be raked into the monorail ash car shown in the drawing. The boilers with which the plant is equipped are of the Buttner make, each with 194 sq.m. (2087 sq.ft.) of heating surface, 119 tubes and a superheater of 50 sq.m. (538 sq.ft.) which give an evaporation of 3600 kg. (7935 lb.) per hour at a temperature of 275 to 300 deg. cent. (527 to 572 deg. fahr.).

The damper arrangement is such that the gases are forced to flow parallel to the walls—in other words, to pass over the entire width of the set of tubes. With the aid of a lever controlled from the front of the boiler the fireman can operate this damper which is made as a balanced butterfly valve. He can also communicate at any time by electrical means with the pulverizing plant, this arrangement being described in detail in the original article. One of the safety measures provided is a special device in front of the boiler which simultaneously and automatically stops both the pulverized-coal delivery and the fan blast, so as to extinguish the fire instantly when necessary under any of the furnaces. The purpose of this device is to prevent damage due to excessive pressure. The apparatus is electrical and consists of a current interrupter controlling both the pulverized coal delivery and the combustion air fans. (*La Nature*, no. 2543, Dec. 30, 1922, pp. 422–426, 6 figs., *dA*)

Short Abstracts of the Month

AERONAUTICS

Loening Flying Control. Description of a type of transverse airplane control which has recently been tested in flight. This control, called a lateral pressure equalizer, is mounted on the extreme tip of each wing.

A small section of the leading edge of the wing is extended out beyond the tip, to which is hinged a pressure-equalizer flap which is controlled through cables and levers by the pilot. It is claimed that with the new device the use of the trailing-edge aileron may be eliminated entirely.

Notwithstanding the fact that the pressure equalizer was tested under bad winter conditions, the ship was found responsive in overcoming wind puffs. (*Aviation*, vol. 14, no. 1, Jan. 1, 1923, p. 13, 1 fig., *d*)

AIR MACHINERY

Determination of Initial Pressure of Centrifugal Ventilators

Tests of Centrifugal Ventilators with Special Reference to Initial Water Gage, Henry C. Harris. It is claimed that very little progress has been made toward the discovery of the most suitable means of determining the initial water gage produced by the running of a ventilator. As a basis for calculation and experiment, the author took the practical example of a fan of large capacity installed to ventilate a mine of small capacity, namely, a Capell fan of the double-drum type 20 ft. in diameter and 6 ft. wide, with a single inlet 11 ft. in diameter and running at 90 r.p.m. The area of the shaft was 70 sq. ft., the area of the fan drift 72 sq. ft., and the area of fan inlet 95 sq. ft. Another series of tests were carried out on a Sirocco fan.

These tests, the results of which are given in the original paper

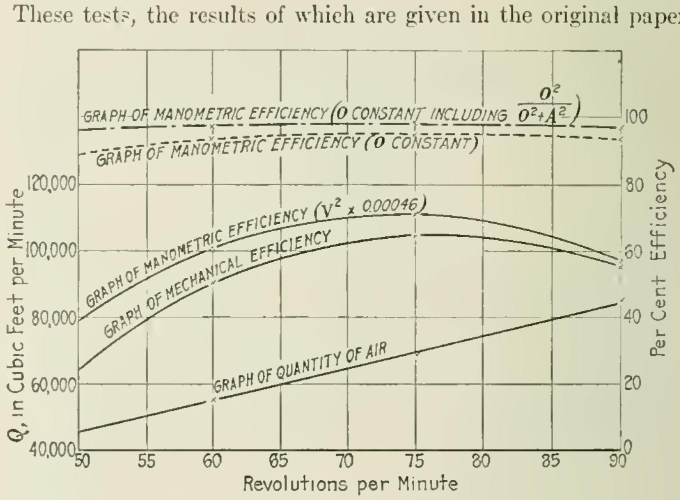


Fig. 1 Graphs of Results of Capell Fan Test

(Full lines for graph of manometric efficiency derived by conventional method; broken lines for those derived by the author's method.)

in the form of tables and curves, of which Fig. 1, for the Capell fan test, is reproduced, have led the writer to ask himself the following questions: (*a*) Why is the manometric efficiency of the ventilator so variable and so low? (*b*) Why does the fan give maximum results at 75 r.p.m. instead of at 90 revolutions as intended, etc.?

In trying to answer these questions the author found that a more consistent method than the conventional one of determining the initial water gage is necessary before any results of tests can be considered reliable, this being due to the fact that in most cases the velocity of the air on leaving the fan chamber which is used in determining the initial water gage, is not identical with the speed of the tips of the fan blades. The author therefore suggests a different method for determining the water gage, and by means of this method he derives the graph shown in Fig. 1 which appears to give results of a more uniform order. It is also claimed that on the basis of the manometric efficiency derived by this method the

maximum results at 70 revolutions instead of at 90 revolutions are consistent for a fan of large capacity ventilating a mine of small capacity. (Paper read December 9, 1922 before the Mining Institute of Scotland, abstracted through *The Iron and Coal Trades Review*, vol. 105, no. 2859, Dec. 15, 1922, pp. 884–885, 2 figs., *ep*)

ENGINEERING MATERIALS

Research Work on Aluminum, Iron, and Electron. Dr. of Engrg. Hanszel. Before the war aluminum alloys usually had a comparatively high tin content, namely, 6 per cent, and, in addition, 2 per cent of copper. Since these metals were scarce during the war, it became necessary to substitute other materials for them, zinc at first being preferred. It was, however, desired that the substitution of the alloying elements should not interfere with the machinability of the alloy and its compressibility. An alloy was therefore produced having an even higher tensile value than the previous standard alloys. It contained 7 per cent zinc, 0.8 per cent magnesium, and the remainder aluminum. Other similar alloys contained 10 per cent zinc and 0.7 to 1 per cent magnesium. These alloys when tested gave rupture strengths as high as 27,000 to 29,000 lb. per sq. in. For one of them (10 per cent zinc and 1 per cent magnesium) it is stated that the elongation was zero. The machinability of the alloys was poor. It was found, however, that the addition of 1 to $1^1/_2$ per cent of tin made them freely machinable. Pressed aluminum rods gave a metal of higher strength, though its machinability appears to have been poor.

The original article gives, among other things, curves showing the influence of adding manganese to aluminum as affecting the strength, elongation, and hardness of pressed round bars. (First of a series in *Canadian Foundryman*, vol. 14, no. 1, Jan., 1923, pp. 26–27, 1 fig., *g*)

Duralumin

An Investigation of Duralumin, Seibei Konno. Data of an investigation carried out at the Tohoku Imperial University, Sendai, Japan. The following conclusions have been reached:

1 In quenched duralumin, the softer the quenching the more the immediate effect of hardening increases, and its aging affect, as well as its final hardness, decreases. In a quenching in oil at 100 deg. or at higher temperatures the aging effect vanishes. On the other hand, the harder the quenching the more the immediate effect decreases, and the aging effect and the final hardness increase, their maximum values being obtained by quenching the alloy from 500 deg. in water.

2 The above effect of quenching is due to the dissolution of Cu and Mg compounds in Al, the process of dissolution or separation being very slow. Thus duralumin is in a somewhat hardened state, even if it is cooled very slowly from 500 deg.; perfect annealing is only obtained by heating the alloy at 350 deg. for one hour or more.

3 The quenching effects on the specific electric resistance of duralumin are very great and exactly similar to those on the hardness. Hence the specific resistance measurement is the most suitable method for the investigation of the hardening of duralumin.

4 The alloys of Al-Cu show by quenching an immediate effect of hardening, but the effect of aging only very slightly. Hence, the immediate effect is partly due to the dissolution of Al_2Cu in aluminum, but the principal cause of the aging effect of duralumin is not attributable to that compound.

5 In the alloys of Al-Mg which contain about one per cent of magnesium, the immediate effect of quenching is always very small, but the aging effect is as great as that of duralumin.

6 The aging effect, as well as the immediate effect of quenching the above alloys, is attributable to the dissolution of Mg_2Si in Al, but not of metallic magnesium; because, if magnesium increases beyond 1 per cent, the above two effects begin to diminish, and with an increase of above 3 per cent of magnesium, almost vanish; but an addition of both magnesium and silicon in the proportion of the compound Mg_2Si increases the same effects. A small quantity of silicon is always present in aluminum as an impurity.

7 The further addition of about 4 per cent of copper and a small quantity of manganese (up to about 0.5 per cent) to the alloys of Al-Mg increases the hardness, but not the aging effect. This alloy, usually called duralumin, has thus nearly the same aging effect as the alloys of Al-Mg.

8 From the specific resistance-temperature curves for quenched duralumin, we conclude that a quenched alloy is tempered at two steps, beginning at 210 deg. and 280 deg., respectively. The first step in the curves is due to the partial separation of Al_2Cu, and the second to that of Mg_2Si.

9 The quenched duralumin expands at room temperature as the aging proceeds, as in quenched low-carbon steels.

10 The above effect of quenching and the accompanying change in the physical properties of duralumin are exactly similar to those in severely quenched carbon steels. Hence we can easily explain the hardening of duralumin by Prof. K. Honda's theory of the hardening of steels.

The paper is accompanied by numerous curves and photomicrographs. (*Science Reports of the Tohoku Imperial University*, First Series, vol. 11, no. 4, Sept., 1922, pp. 269–294, 6 figs., 9 plates, *eA*)

FUELS AND FIRING (See Motor-Car Engineering)

HYDRAULIC MACHINERY

Chain-Type Water Elevators—Tests

Tests of Caruelle Water Elevators. These water elevators, also called "Chaine-Helice," have been described in *Engineering*, vol. 98, 1914, p. 40, and are used mainly for raising water from open wells to the ground level.

The device consists of belts made up of strips of sheet aluminum alloy bent so as to form a series of triangular cells, the cells being riveted to a flexible supporting element, which, in the case of the smaller sizes, is a band of aluminum bronze. In the larger sizes balata belting is used to support the aluminum cells, a number of which are placed side by side. Large driving and jockey pulleys are used with these belts in order to reduce the bending to a minimum and grooves are turned in both pulleys to clear the rivet heads so that the latter are not worn away. A feature of this device which is particularly useful in the case of hand-driven installations is that they remain filled with water when stationary and if a ratchet is provided to prevent the belt from running back, due to the weight of the entrained water, delivery will commence as soon as the belt is set in motion. This is important with deep wells pumped intermittently at frequent intervals.

The tests were carried out by Sir Alfred Chatterton of the Indian Public Works Department and Arthur S. Collins, City Engineer of Norwich. In these tests two belts were used, the lifting elements of one measuring $^7/_8$ in. wide and $^5/_8$ in. deep, and those of the second $1^5/_{16}$ in. wide and 1 in. deep. The aluminum-bronze bands to which the elements were riveted were 1 in. and $1^3/_8$ in. wide, respectively, and in both cases the pitch of the triangular cells was $^1/_2$ in. The drive was by means of a leather belt from an electric motor, so arranged that the torque exerted could be measured. The lift in all cases was 152 ft. 6 in.

The results are given in diagrams in the original article. With the smaller belt a maximum net efficiency of 95 per cent was obtained with a linear speed of about 7 ft. per sec., but the efficiency fell off rather rapidly as the speed increased. In the case of the larger belt the maximum efficiency reached was practically the same, but was maintained over a wider range of speeds, only falling to 85 per cent at 13.4 ft. per sec. The maximum overall efficiency with the larger band was much higher than that obtained with the smaller band, the former reaching over 74 per cent and the latter about 58 per cent. Owing to the short distance between the centers of the driving and driven pulleys, rendered unavoidable by the existence of buildings close to the wall, a very tight belt had to be employed. This absorbed an undue amount of power and materially reduced the overall efficiency in both cases.

The tests have also shown that the larger belt gives a much wider range of deliveries with good efficiency, the maximum efficiency being reached at about 950 gal. per hr.

Another series of tests was made by the same authorities with the water-elevating belt made up of four sets of cells of the larger size of the two above described, riveted on to a balata belt. Here it was found that to obtain the highest efficiency with water elevators of this type, it is important that the immersion of the jockey pulley should be only sufficient to allow the belt to fill completely, a condition which would not always be complied with in practice.

It is claimed, however, that the advantages of simplicity, reliability, and general good efficiency are more than sufficient to compensate for this drawback. (*Engineering*, vol. 114, no. 2973, Dec. 22, 1922, pp. 770–771, 5 figs., *e*)

INTERNAL-COMBUSTION ENGINEERING (See also Motor-Car Engineering)

Ripert Motor with Steam Chamber in Head

The Ripert Motor, M. Grison. It is claimed that the following conditions, if satisfied, would improve the Diesel engine when operating on heavy oils and, in particular, would make it more flexible.

First, introduction of the oil into pure air not only at the dead center but ahead of it, namely, toward the end of the compression, in order to obtain a vaporization and diffusion of the oil through

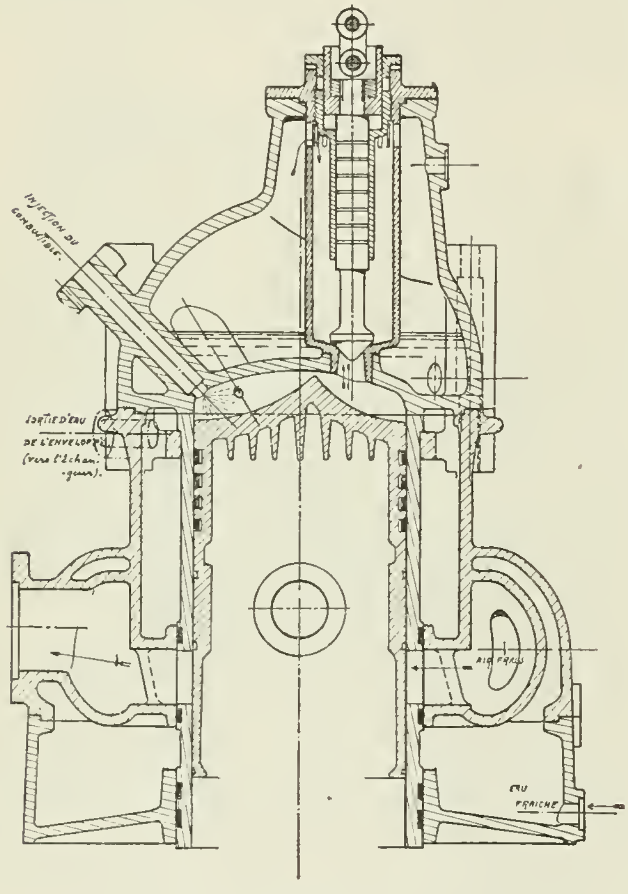


Fig. 2 Ripert Oil Engine

(*Injection du combustible* = fuel injection; *sortie d'eau de l'enveloppe* = exit of water from jacket; *air frais* = fresh air; *eau fraiche* = fresh water.)

the air during the heating of the latter. The fuel being introduced during compression, the atomizer meets with only a relatively low pressure in the cylinder. It therefore works more efficiently. The fuel injection takes place without air injection, which eliminates the unfavorable refrigerating action of the latter. This of course makes the high-pressure compressor together with its appurtenances unnecessary.

The second condition is that the compression should continue up to the dead center, and hence a temperature should be attained close to that necessary for spontaneous ignition. As the fuel has already been distributed through the entire mass of the air and heated with it at the same time, the ignition can take place at the dead center throughout the whole charge simultaneously and have all the characteristics of an explosion.

During combustion a certain amount of water vapor should be introduced into the cylinder both because of its influence on the gas and on account of the well-known catalytic effect which assists the combustion of the heavier particles of tar oils. The steam helps to prevent the formation of coke deposits and improves the lubrication of the cylinder and hence the mechanical efficiency. With accelerated combustion and assured cooling it would not be necessary any longer to induct into the cylinder as great an excess of air as in the Diesel engine (thirty times the weight of the oil), which would increase the volumetric efficiency. Finally, the possible increase in the revolutions would tend to reduce the weight and first cost of the machine.

It is said that the Ripert motor (Fig. 2) was designed with the view of realizing as completely as possible the foregoing theoretical considerations. The drawing shows a two-stroke-cycle motor. The construction differs from that of the Diesel engine solely in the cylinder-head arrangement, which, in the Ripert motor, forms a kind of boiler. It is supplied with water in such a manner as to maintain automatically its internal temperature at about 250 deg. cent. (482 deg. fahr.) and the steam pressure at 30 kg. (428 lb. per sq. in.) approximately, although in both cases higher values may be employed.

Water feeding is effected by means of a small pump whose output is automatically controlled by a thermostat. This pump is independent of the speed of the motor. The water may be taken from the cylinder jacket and preheated by exhaust gases before being fed into the cylinder head, where it is superheated to the necessary extent. This plan is used, however, only with large motors. There is no trouble in maintaining a certain level of water in the cylinder head. The boiler in the head communicates with the combustion chamber in the cylinder by means of a valve.

The Ripert motor may operate with or without steam admission. If it is operated without steam admission when the piston is at its lower dead center, air is supplied to the cylinder either by crankcase compression or by a special pump. About the middle of the compression stroke or somewhat later heavy oil is introduced by solid injection. The temperature is then sufficient to vaporize the atomized oil and prevent its precipitation. The piston then proceeds to complete its upward stroke. At the same time the compression is regulated in such a manner as to develop the highest possible temperature, which would not, however, reach that of auto-ignition.

A few degrees before the dead center is reached, the valve communicating with the cylinder head is opened and the clearance space placed in communication with the head into which compressed air has been forced before starting the motor. This is done only once in the course of operating an engine. The compressed air at a pressure of about 30 kg. (428 lb. per sq. in.) penetrates with its excessive pressure into the clearance space and suddenly forces the mixture back toward one of the sides of the deflector of the piston, producing a strong mixing effect, this being assisted also by the shape of the top of the piston and the compression chamber. Ignition then takes place spontaneously on account of excessive pressure. The explosion forces back into the head the air which came out of it along with some of the gaseous products of combustion. When at the beginning of the expansion stroke the pressure in the head has become equal to what it was at the beginning of the cycle the communicating valve is closed, the expansion in the cylinder itself continuing. With this arrangement it is not necessary to renew the compressed-air charge in the cylinder head as it renews itself automatically, though after some time the air is replaced by gases of combustion.

It is important to note that this cycle is not really the one on which the Ripert motor works, although it is not impossible. The true cycle of the Ripert motor is one in which steam is introduced into the cylinder. This steam, at a pressure of 30 kg. (428 lb. per sq. in.) or more, is contained in the cylinder head and suddenly forces back the cylinder mixture.

The position of the valve with respect to the deflector at the top of the piston is such that during the mixing period a relative stratification of the two fluids, steam and gas, is maintained. At the end of the period of steam injection one part of the chamber is still filled with steam, while in the other the gases (air and oil vapor) are collected.

The ignition occurs throughout the entire mixture at exactly the predetermined moment, either spontaneously as a result of excessive compression, or in the case of semi-Diesel engines, by sudden forcing of the mixture into a preheated chamber or electrical ignition tube. The combustion takes place throughout the entire charge in the form of an explosion. During this explosion while the pressure in the cylinder becomes greater than the pressure

of the steam introduced into it, the steam flows back into the cylinder-head chamber through the valve as long as it remains open. Eventually a certain amount of gas penetrates into the cylinder head chamber in accordance with the point to which it is desired to limit the maximum pressure of the explosion. In multi-cylinder engines the cylinder heads communicate and form a single boiler which insures the uniformity of pressures resulting from the explosions in each cylinder, notwithstanding the unavoidable variations in fuel feeding.

As soon as the downward movement of the piston reduces the internal pressure the gases from the cylinder-head chamber flow back into the cylinder, passing through the valve which is still open in the opposite direction and along with these gases a certain amount of steam enters the cylinder and stays there. When the pressure falls sufficiently low the valve closes. The expansion and exhaust portions of the cycle do not differ from those in conventional engines. The theoretical calculation of the original cycle is given in the original article.

No data of tests are adduced. Some diagrams are given containing "practical" figures, but it is not stated how they are obtained. (*Bulletin Technique du Bureau Veritas*, vol. 4, no. 10, Oct., 1922, pp. 245–247, 2 figs., *gt*)

High-Compression Gasoline Engines

Internal-Combustion-Engine Characteristics Under High Compression, J. H. Holloway, H. A. Huebotter and G. A. Young, Mem. Am.Soc.M.E. This paper is a report of a series of tests conducted during the summer of 1922 by the authors at the Engineering Experiment Station of Purdue University. The work consisted of research into the operation of internal-combustion engines under comparatively high compression on ordinary gasoline without detonation. The compression ratio of the engine was 6.75 and the compression pressure 122 lb. per sq. in. gage. The ingoing charge was passed through a hot-spot vaporizer and thence through a cooler between the carburetor and the valves. Jacket-water temperatures between 150 and 170 deg. fahr. were carried at the outlet port of the jacket.

The theory held by the authors as to the causes of detonation of combustible charge is presented briefly. The source of the two phases of detonation encountered in this work is believed to be overheated areas in the combustion chamber. The methods of combating these hot spots are given in detail, and the special equipment applied to the engine to accomplish the desired result is described. The effects of load, speed, compression ratio and mixture ratio are studied, and curves showing the variation in the engine characteristics due to each factor are submitted. All tests were run without a trace of detonation.

From these tests, which are represented as covering only a narrow range in the field of gasoline-engine operation, the following conclusions are drawn:

1 Under laboratory conditions a compression pressure of 120 lb. per sq. in. gage is perfectly feasible when the engine is designed with a full regard for the elimination of the factors that induce detonation.

2 Under service conditions the same attention to these factors will permit the use of much higher pressures than those common at present.

3 An increase in the compression ratio results in a marked improvement in the thermal efficiency and the general performance of the engine at all loads and in the maximum power at all speeds.

4 The sources of detonation are the spark plug, the exhaust valve, the piston head, and any other portions of the combustion-chamber walls that become overheated.

5 The maximum economy is obtained with the leanest fuel-air mixture giving reliable combustion. Such a mixture varies from 0.060 lb. of fuel per lb. of dry air at 25 per cent load, to 0.057 lb. at 75 per cent load; or, from 16.6 to 17.5 lb. of dry air per lb. of fuel. Hence, for this range of load the leanest possible mixture is desirable, provided good vaporization is secured. At a full throttle opening the maximum power is usually sought at the expanse of economy. An 0.075 mixture, or 13.3 lb. of air per lb. of fuel, is rich enough to insure the greatest output.

6 The water-jacket heat loss reaches its maximum value at approximately the mixture giving the highest power with a fixed throttle opening, or a 0.075 ratio.

7 Exhaust temperature is highest with a 0.065 ratio.

8 The power of an engine can be increased 25 per cent by a change in the compression ratio from 4.45 to 6.75, provided detonation is absent.

9 With the same change in the compression ratio the thermal efficiency is raised 7 to 12 per cent through a load range of 25 to100 per cent of the engine power.

10 At full load a mixture temperature of 125 deg. fahr. at the hot spot is high enough to give good distribution in a four-cylinder engine with a properly designed hot spot. If the mixture is cooled below this temperature between the hot spot and the valves, the performance of the engine is improved. A low limit of 100 deg. fahr. at the valves can be allowed safely.

11 At partial throttle opening, a hot-spot temperature of 175 deg. fahr. is not excessive and assists in the use of very lean mixtures for high economy. (*Journal of the Society of Automotive Engineers*, vol. 12, no. 1, Jan., 1923, pp. 111–117, 11 figs., *e*)

Hammer-Spray Injection System. Details of a device for enabling gasoline engines to use kerosene and light fuel oils such as oil of about 34 and 36 deg. B. (Development of the Hasbrouck patents.)

The system consists of a spray of fuel injected into the combustion chamber of each cylinder of the engine by a pump by means of a sudden blow of a hammer on the plunger of the pump. The fuel is injected into the cylinder through a spray nozzle to which flexible tubing is led from a pump; the plunger of this pump is actuated at the proper moment for injection of fuel by a hammer operated by a spring under moderate tension and by a trip cam mounted on a shaft driven by means of a belt, chain or the like.

It is said that when the plunger of the pump is driven down by the blow of the hammer the correct amount of fuel is forced through the tubing past a ball check and injected in a very finely pulverized spray between the seat of the valve and the spherical surface of the valve head against the tension of the spring. One pump plunger and one spray nozzle are required for each cylinder.

Tests of this device have been made by Prof. E. H. Lockwood, Mem. A.S.M.E., of Mason Laboratory of Sheffield Scientific School, Yale University, and two installations have been in service on boats at New Haven for many months. Of the tests made, one was in connection with a single-cylinder four-cycle stationary engine of $4^5/_8$ in. bore and 5 in. stroke, which operated on 36-deg. B. oil and with 25 lb. cylinder compression, starting cold with relieved compression on the second turn of the flywheel after standing idle for over six months. This engine also operated on alcohol and kerosene with this device installed. A single-cylinder two-cycle marine engine of similar bore and stroke was tested by Professor Lockwood, and is now driving a 23-ft. by 9 ft. 6-in. converted catboat about $5^1/_2$ m.p.h. This engine starts cold directly on kerosene or fuel oil on 35 lb. compression, and the consumption is moderate, one gallon sufficing for two hours and twenty minutes' running. (*Motorship*, vol. 8, no. 2, Feb., 1923, p. 118, 3 figs., *d*)

MACHINE PARTS AND DESIGN

Belt Transmission, D. Genkin. An extensive, largely mathematical analysis of belt transmission. As a rule, in computing the efficiency of belt transmissions only losses on pulleys are considered. In the present instance the author, after reviewing the known formulas, endeavors to determine the magnitude of all the other losses. Among other things, he calls attention to the undesirability of using belts in power transmission from an electric motor.

The conclusions at which he arrives are that no matter how carefully belt transmission may be designed and worked out, the power losses inherent in this type of transmission can rarely be brought below the five per cent level. As regards less carefully designed belt transmissions, the losses involved therein may not only be in excess of all reasonable limits but may cause a rapid wear of the bearings and frequent stoppages of work due to the wear on the belt itself.

The article itself, after a brief introduction, proceeds to a mathematical study of the operation of a belt transmission, which, among other things, investigates the relation between the initial tensions on the tight and loose sides of the belt, the variation of tension

along the portion of the belt in contact with the rim of the pulley, the effect of elongation of the belt in running, and the calculation of the suction of the belt.

The selection of the best tension in the belt is discussed, after which an extensive abstract is quoted from Taylor's work on Shop Management.

The losses due to periodic elongation and contraction of the belt are mathematically discussed, likewise the losses due to the resistance of the belt bending around the pulley. (*Revue Générale de L'Electricite*, vol. 12, no. 25, Dec. 23, 1922, pp. 975–988, 5 figs., *mtA*)

MACHINE TOOLS

Pull or Push Cutting Strokes, F. H. B. One of the problems in the use of certain types of machine tools is whether the cut shall be taken on the pulling or the pushing stroke. This consideration applies to such machines as possess holders or rams carrying the tool out from the end. In such a category come shapers, broaching, keyway-cutting and filing machines, hacksaws and some of the gear shapers. The primal difference in cutting on the pull or the push stroke is that of change from tension to compression, a change which may affect all the elements: the tool, the ram, its slides and the means of propulsion. In discussing the advantages or disadvantages of either method the author cites the ordinary pillar shaper where the presumed advantage of the pulling stroke, namely, consolidating the slides of the table and saddle by the cutting pressure, is discounted by the fact that substantial table supports are now employed in most of the ordinary shapers to withstand the downward and outward thrusts.

The author discusses in detail keyseating machines, broaches, hacksaws and gear shapers. In keyseaters a draw cut may be usefully employed if long hubs require it for keyways cut in their bores.

In case of gear shapers both the push stroke and the draw stroke may be used, the latter being employed in the Fellows shaper which possesses a vertical ram. There are, however, shapes that cannot be cut on the pulling stroke, for example, gear clusters, where owing to the contiguity of another tooth ring, the cutter cannot start up from below. However, the design of the spindle end of the Fellows machine permits of fixing on the cutters for either the push or the pull stroke without trouble. (*Mechanical World*, vol. 73, no. 1879, Jan. 5, 1923, pp. 2–3, 3 figs., *p*)

MARINE ENGINEERING (See Special Processes)

MEASUREMENTS

Passing of the Quarter. On January 1, 1923, by an amendment to the Corn Sales Act the hundredweight has become the sole legal standard for sales of dry products in Great Britain and Ulster, thus eliminating the quarter as the legal measure.

The bushel or small box was the ancient unit of Saxon dry measure. The quarter was eight bushels and the system was to buy by measure, quality being roughly appraised by weight. For more than a century, however, there has been a tendency on the part of buyers to insist on sales by uniform weight, in addition to which the measure "quarter" was uniform throughout the country. (*The Times Trade and Engineering Supplement*, vol. 11, no. 237, Jan. 20, 1923, p. 429, *g*)

METALLURGY (See Engineering Materials)

MOTOR-CAR ENGINEERING

Alcohol as Fuel. One of the main difficulties in the use of alcohol in engines is that of starting. This has, however, been solved by the so-called bi-fuel scheme in which starting is done on gasoline and running on alcohol.

In this connection, the original article describes the gasoline-alcohol Claudel-Hobson carburetor and the so-called Hobson non-pinker, a device to prevent "pinking" (detonation knock) in high-compression engines, of importance because with alcohol the higher compression is needed than with gasoline.

The device consists of a diaphragm-control needle valve in a small auxiliary carburetor so connected to the main carburetor that at periods when the depression in the main carburetor is low the device comes into operation and allows alcohol to feed to the cylinders. The depression is low when the throttle is open and high when it is closed. Therefore the alcohol is fed to the cylinders and cut off again exactly at the required moment. (*The Autocar*, vol. 49, no. 1419, Dec. 29, 1922, pp. 1310–1311, 2 figs., *dg*)

A Six-Wheel Motor Omnibus

Six-Wheel Motor Omnibus in Paris. Description of a new type of motor omnibus being placed in operation in Paris. One of the obstacles in the way of more efficient utilization of motor omnibuses is their limited seating capacity. Thus, while the ordinary trolley car can carry up to 100 passengers and more in rush hours, a motor omnibus in Paris has only 38 seats. To increase the seating capacity, seats would have to be provided on top, an arrangement which has not proved popular in Paris although extentensively used elsewhere, as, for example, in England. One way to meet this situation was to increase the overall wheelbase by

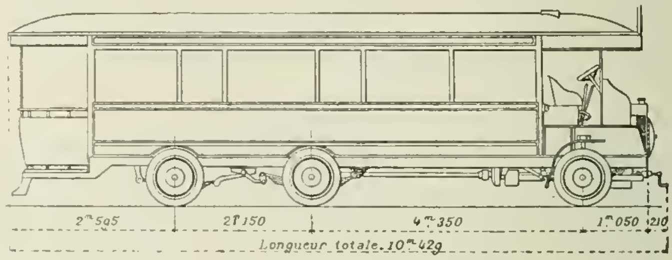


Fig 3 Six-Wheel Motor Omnibus in Paris
(*Longueur totale* = total length.

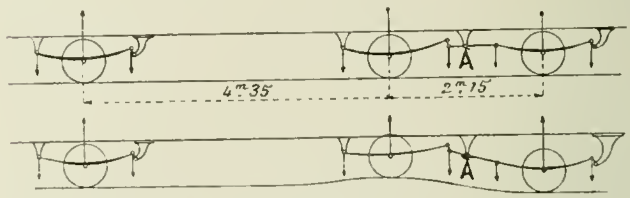


Fig. 4 Balanced Suspension Arrangement of the Paris Six-Wheel Motor Bus

providing an intermediary axle, which meant a six-wheel arrangement and raising the seating capacity to 48 seats. Fifty such buses are already under construction.

The new bus has a total length of 10.43 m. (34.4 ft.) and a width of 2.25 m. (7.25 ft.). The axles are spaced unequally, the front axle being 4.35 m. (14.4 ft.) and the rear axle 2.15 m. (6.90 ft.) from the middle axle, the total wheel base being therefore 6.50 m. (21.30 ft.). The steering is on the front and rear axles only. All the wheels have the same diameter 0.95 m. (37.4 in.). The front and rear set are equipped with single solid tires, the middle wheels with double tires of the same section.

The chassis is equipped with a special device for maintaining constant the distribution of load on the wheels. In a vehicle carried on two axles this distribution does not change materially notwithstanding variations in level of the road, but this would not be the case in a vehicle carried on six wheels, unless special means were taken to accomplish it (in this case a balancing gear joining the extreme tips of the rear and middle springs). This balancer *A* (Fig. 4) oscillates about a shaft carried in a support rigidly held on the chassis. This being so, the system of forces acting on the chassis is of a statically determinate nature and the reactions on the wheels are independent of the relative position of the latter. The loads on the steerable wheels may be equalized by suitably locating the middle axle, which is also very useful from the point of view of stabilization of direction. Another advantage of a balanced suspension is that it decreases the vertical movements of the carriage, which reduces the jarring and the wear both on the omnibus and the road.

The vehicle is provided with a mechanism brake, a wheel brake and an auxiliary braking device acting on the middle wheels and operable from the rear platform.

The omnibus (Fig. 3) has an interesting steering system which cannot be described here on account of lack of space. It is pointed out in this article, however, that a six-wheel car has less tendency to skidding than one running on four wheels. (*Le Génie Civil*, vol. 81, no. 27, Dec. 30, 1922, pp. 605–607, 11 figs., *d*)

Aster Engine Valve Gear

The "Eighteen Six" Aster. Description of the Aster automobile, built by a British company which for 22 years has manufactured engines for automobiles.

One of the interesting features of this engine is its valve-operating gear (Fig. 5). The valves are directly overhead and in line. They are operated by rocker levers, the ends of which are pushed up by push rods from the tappet gear above the camshaft. The latter is silent-chain driven and is located in the crankcase. The two features of this gear are the absence of working bearings in the rockers and the provision of silent oil cushioning to the tappets and push-rod gears.

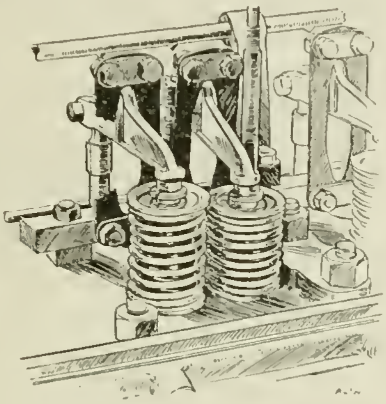


Fig. 5 Valve-Operating Gear of the Aster Engine

The rockers instead of being pivotally mounted on trunnion bearings as is the conventional practice, are rigidly bolted to upstanding steel spring pillars which curve to allow the outer ends of the levers to depress the valves. The push rods are provided with ground spherical seatings, carefully constructed so that there will always be a film of oil between the opposed surfaces. This is said to insure silence. The measure of the accuracy of the fit here is important, and the spherical surfaces are very carefully machined and ground in order that an oil film shall always be present between them.

The fan is provided with a telescopic adjustment for height in order to allow of the adjustment of the belt. The adjustment is fixed by a small hand lever and can be made without the use of tools.

One of the minor features is that the water outlet pipe from the cylinder head to the top of the radiator is stayed by a couple of stay rods at the side, which have the effect of staying the radiator to the engine. Another point about the engine design is the use of a small air pump driven by a cam on the camshaft and providing air pressure for the rear-tank fuel supply to the carburetor. This pump is fitted with a release valve which is in an accessible position, is easily adjustable from the outside, and may be readily dismantled should occasion arise for any adjustment or examination.

The transmission of the power from the gear is carried out by means of an enclosed propeller shaft which runs in a long tapered torque tube forming the forward extension of the live axle The function of this tube is to take the torque and the propulsion loads. (*The Auto-Motor Journal*, vol. 28, no. 2/1149, Jan. 11, 1923, pp. 27–30, 11 figs., *d*)

POWER-PLANT ENGINEERING (See also Special Processes)

The Design of Structural Supports for Turbo-Generators, Edward H. Cameron. Discussion of the relative merits of the three common types of pedestals for turbo-generators, namely, reinforced concrete, structural steel, and composite. The author believes that the tendency of the steel pedestal to vibrate with the machine constitutes its one disadvantage when compared with the concrete pedestal, and the design of a steel pedestal so proportioned as to avoid this vibration is a difficult problem.

The pedestal must have mass enough to absorb all vibrations and be rigid enough to prevent swaying. The most practical means of arriving at the requisite mass for a turbo-generator pedestal is by a study of existing designs in satisfactory operation both as to total mass and its distribution. To facilitate this the author gives weight-ratio curves and cost curves.

The original article gives a series of practical suggestions as to the best method of proceeding in designing pedestals for turbo-generators, the general advice being that utility or fitness rather than relative cost should be made the sole basis of comparison in deciding on the type of pedestal to adopt for a turbo-generator installation. As regards costs it is stated that for ordinary designs the cost of the pedestal should not exceed about 5 per cent that of the turbo-generator, and that in general any saving of one particular type of pedestal over another should not be more than about 1 per cent of the cost of the unit which it supports. Each type of pedestal has its field. For the smaller units it is believed that more concrete pedestals are in use, whereas the reverse is probably true of the larger units. The composite type, combining the advantages of both concrete and structural steel, is coming to be more and more favored for all sizes of turbo-generator units. (Paper before the Monthly Meeting, Dec. 20, 1922, of the *American Society of Civil Engineers*, abstracted from advance publication, 16, pp., 6 figs., *p*)

Increase of Economy by Changes in Boiler Design

Principles of Boiler Design, C. E. Stromeyer. Discussion of some features of boiler design, with particular reference to attempts to increase economy.

In view of the injury done to boiler parts and to brickwork if the furnace temperature is high, as it must be with perfect combustion, the author suggested some years ago the resort to double combustion. The fuel in the furnace would be burned not to carbon dioxide but to monoxide. The resultant temperature could then not exceed about 2500 deg. fahr. and the temperature curve in the boiler would run in a manner entirely different from that of today. This arrangement would present difficulties when using customary types of boilers and the present types are merely to be modified. There would be difficulties from the increase of furnace temperature and, in particular, from enormous heat radiations, which brings up the question as to whether heating surfaces can be screened from the radiation of the incandescent fuel.

Assuming that the radiant heat of the furnace has been disposed of one way or another, we are face to face with the question of convection. Let there be two fluids of different densities on both sides of a plate—heating surface—then, neglecting the very slight resistance offered by the plate to the passage through it of a certain quantity of heat H per hour, it appears that—

$$H = C\,(T_1 - T_0)\,D_1\,(1 + 0.02\,V_1) = c\,(T_0 - T_2)\,D_2\,(1 + 0.02V_2).$$

Here C is a constant which is, however, not quite the same for all gases and fluids. T stands for the various temperatures, T_0 being that of the plate, D stands for densities and V for velocities in feet per second. The two right-hand expressions determine the ratio of the subdivision of the available temperature difference $T_1 - T_2$. The ratio is $(T_1 - T_0)/(T_0 - T_2) = (D_2/D_1)\ (1 + 0.02\,V_2)/(1 + 0.02\,V_1)$. Let the one fluid be water, whose density is about 800 times as great as that of air, then for small values of V the ratio of the excess temperature of the air over the plate, $T_1 - T_0$, would have to be about 800 times the excess temperature of the plate over that of the water $T_0 - T_2$. To increase V_2 would only increase this disproportion, but this would be diminished, and the heat transmission per square foot of heating surface increased, if the air velocity V_1 were increased. Our efforts should therefore be centered on increasing the velocities of gases and steam and not on increasing the water velocity, except, of course, for circulating purposes and for liberating the steam as it is generated.

It could easily be shown that a minimum heating surface will be obtained if the temperature ratio $(T_1 - T_0)/(T_0 - T_1)$ is near unity. This is of importance as regards superheaters.

The problem of creation of the draft velocities is discussed and the author shows that the cost of a draft produced without a chimney and with gases cooled down to the surrounding temperature with the fan will be very much lower than when produced by natural draft in terms of coal used. Nevertheless, fans do not replace chimneys, because with present-day boilers the temperature of the waste gases cannot be reduced much below 400 deg. fahr., and because chimneys are necessary anyway to carry the gases above the housetops.

From this the author proceeds to a discussion of the employment of air heaters as a possible means of waste-gas cooling and shows the many difficulties involved in their design.

He considers the superheater a necessary adjunct of modern engines and makes an estimate of the relative velocities, using however, relative densities instead of temperatures in the calculations. The steam velocities, he says, should be less than those of the gases, but both should be high. The loss of power in the main engine, due to drop of steam pressure in the superheater, should be estimated, also the increased friction in the steam pipe due to increased volume, or increased radiation, due to the adoption of slightly larger diameters. The simplest way out of this complication would probably be to start with the pressure required at the engine, and to make the boiler strong enough to bear the few additions. The problem is then reduced to the simple one of taking into account the increased cost of the boiler due to the small increase of pressure. Steam users should not expect to gain in both directions. If by employing high velocities the superheater surface has been reduced, a loss of steam pressure must result. But steam users would have cause to complain if only one of the velocities were kept high, for then there would be friction losses with only one-half the possible gain.

The interesting problem has now to be solved as to where the superheater should be placed. It certainly cannot be placed next to the air heater, because here the temperatures are too low. The further we move away from the air heater, the hotter will be the waste-gas temperature, the better the heat transmission, the smaller the heating surface required, and the lower, if desired, can the velocity of steam and gas be fixed. The cost of each alternative would have to be worked out.

This is followed by a discussion of economizers, high velocity of flames (based on the experiments of Professor Nicolson), reductions of furnace temperatures and oil burning. (From a Report to the Manchester Steam Users' Association, 1922, abstracted through *The Engineer*, vol. 134, no. 3495, Dec. 22, 1922, pp. 672–673, *gt*. Compare editorial, dealing with other parts of the same report in the same issue of *The Engineer*, p. 669)

Steam Velocity. In an editorial a question is asked as to whether we should guess or know what the maximum steam velocity in a steam pipe should be, and whether it should be 6000 ft. per min. or 20,000. If 6000 is used where 20,000 would give entirely satisfactory results, a lot of money is wasted. On the other hand, if excessively high velocities are used, trouble is certain.

Most of our formulas for the flow of steam through piping and fittings were inherited from the era of low pressures and saturated steam, and it is the opinion of many practical designers that they are totally inadequate for the conditions found in large stations. Moreover, it appears that the laying out of steam pipes on a velocity basis is satisfactory only where a wide range of velocities is used to fit various conditions.

In this connection, considerable interest attaches to the recent statement of John H. Lawrence, Mem. Am.Soc.M.E.—who has had extensive experience in power-station design—that the proper steam velocities for the conditions found in large modern power stations may be roughly approximated by allowing 1000 ft. per min. velocity for each inch of pipe diameter. If this rule is approximately correct, it is seen that 6000 ft. per sec., while about right for a 6-in. pipe, is far too low for a 20-in. pipe. This rule of thumb was not proposed by Mr. Lawrence as a hard-and-fast law of good practice, but merely as something tangible in the field between pure guesswork on the one hand and incorrect formulas on the other. In reference to the latter Mr. Lawrence said that actual measurements at the Hell Gate Station showed pressure drops far lower than those figured by any of the standard formulas for steam flow. As to losses through fittings and valves, the condition of knowledge is, he said, even more chaotic.

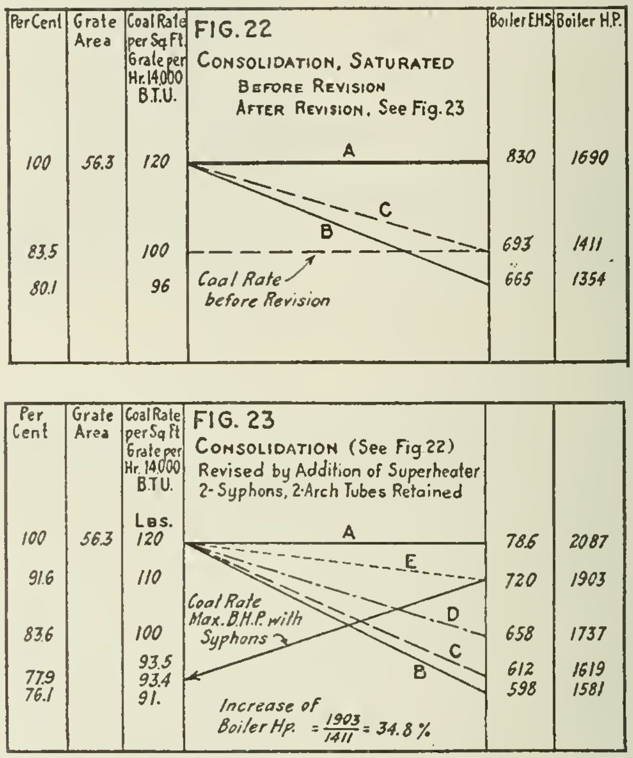
The writer expresses the hope that The American Society of Mechanical Engineers will follow the suggestions of those members who are fully alive to the importance of this problem, and believes that it should certainly be worth while to make an extensive field survey to determine the actual pressure drops obtained with the various fittings, pipe sizes, pressures, superheats and steam velocities found in existing plants. From a careful study of the tabulated data of such a survey it should be possible to develop formulas suitable to the need of the practical designer. (Editorial in *Power*, vol. 57, no. 3, Jan. 16, 1923, pp. 105–6, *p*)

RAILROAD ENGINEERING

Graphical Analysis of Locomotive Boiler Proportions

Graphical Analysis of Locomotive Boiler Proportions, C. A. Seley. A graphical analysis of locomotive boiler proportions developed with particular reference to the design of locomotives equipped with the so-called thermic siphon (For description of the thermic siphon, see Mechanical Engineering, March, 1919, p. 284). It is based on the engineering methods and data proposed by F. J. Cole in designing boilers on horsepower basis.

The article is not generally suitable for abstracting, but some of the conclusions arrived at may be reported here. One of the figures (No. 16) illustrates the results of insufficient grate surface, which means high coal-burning rates and loss of economy and efficiency. It has been stated that a 120-lb. coal rate is about the maximum amount for economical evaporation, yet this diagram shows 134 lb., a very high rate for continued heavy service. The United States



Figs. 6 and 7 Diagrams of Consolidation Locomotive Before and After Revision

(The figure numbers above refer to the illustrations as placed in the original article.)

Railroad Administration 2-6-6-2 design is in a similar class, with high coal rate for heavy service.

A claim is made in the article that some of the deficiencies of present-day locomotives may be compensated for by the addition of a thermic siphon. By way of illustration of these claims the following may be cited:

An increase of tonnage rating of 20 per cent sounds big, but is actually being accomplished in the revision of a series of Consolidation locomotives originally heavily built and capable of such increase in tractive effort by cylinder and steam-pressure changes. The original boiler had four arch tubes but no superheater and was of 1411 boiler hp. The boiler revision consisted of superheating, adding two siphons, retaining two arch tubes, the combined effect being to give an equivalent equated heating surface of 720 sq. ft. or 1903 boiler hp., an increase of 35 per cent, with a very moderate coal rate, all as shown in Fig. 6.

Fig. 7 shows distribution in percentage of the heating surfaces and the effect of the revised design, as compared with the original dimensions equated to superheat ratio for comparison, or 74.14 per cent. The revised locomotive has successfully handled an increase of 20 per cent and over of the original engine tonnage rating, and, while this is an exceptional case, due to some of the features involved, no doubt, there are many locomotives that are

capable of a similar line of treatment. (*Railway and Locomotive Engineering*, vol. 36, no. 1, Jan., 1923, pp. 9–13, 24 figs., *cg*)

European All-Steel Sleeping Cars

European All-Steel Sleeping Car, Wm. Redpath. Description of what is said to be the latest word in Continental sleeping-car construction. These are not only the first all-steel sleeping cars built abroad, but the first European cars in which steel castings have been extensively employed to strengthen and simplify underframe and truck construction.

The whole of the structure of the body is of steel, the sides being constructed with 1/8-in. pressed-steel members of varying sections connected longitudinally to rolled-section angles at the base which rest on the underframes. At the top the vertical members are connected by the two angle rails. The sides below the waist are sheeted with 1/8-in. steel sheets of a special quality which give a superior finish. The sheeting above the waist is pressed in 1/8-in. plate to form the window openings, as many as four windows being pressed in one piece. Steel moldings are used to cover the butt joints of the body side plates, the whole side being riveted together with rivets countersunk on the outside to give a clean appearance to the outside of the coach. The sides thus become deep girders capable of supporting the whole of the superstructure.

The roof is elliptical, being constructed of a rolled-section angle carline riveted to upper partition plates. These latter extend down to the cantrail level across compartments and are shaped to suit the ceiling at the corridor. The roof is designed to allow of the water tanks being assembled or removed through the outside sheeting, covers with suitable joints being provided.

The structure of the body is entirely of steel, being built in jigs in units: full-length compartment side, full-length corridor side, full-length roof, body ends, platform ends and canopies, thus insuring complete interchangeability as well as ease of production. These units, which for the most part consist of pressings and rolled sections all machined to templets, are quickly assembled whole on the underframe, leaving the shell ready for the assembling of interior finish. To insure absence of vibration and drumming, the steelwork has been covered on the inside with canvas and insulation from heat, and cold has been well provided for. Free air circulation between the outer skin and inner finish is also arranged for the prevention of condensation.

These cars are arranged essentially in a different manner from sleeping cars in America. They have been designed to carry sixteen passengers, the arrangement being eight single compartments, four double compartments, and two lavatories, six of the single compartments being provided with communicating doors capable of being locked from either side. The seats of each compartment turn over to form the bed, the bedding being secured to the undersides of the seats in dustproof envelopes. The seat back of the double compartment is arranged to lift to a horizontal position to form an upper berth, being supported by pull-out brackets fixed to the body side and corridor partition; safety straps supported from the ceiling are also provided.

There are other facilities not available in American sleeping cars. Thus, incorporated with the vestibule ends are cupboards for ice and wine, utensils and coal, with linen cupboards in the ceiling. The cool wine cupboards are insulated with asbestos and are zinc-lined.

There are two heating systems: one, the usual through steam heating, and the other by hot-water circulation. For the latter a heating chamber is provided at one end of the corridor at which is fixed a coal-fired boiler; circulating pipes of copper are run from boiler to a hot-water tank in the roof, and from this around both sides of the car.

As the cars run over many railway systems, some of which use vacuum and others compressed air, it has been necessary to arrange the brake rigging for use with either system. When the vehicles are in use for the vacuum system, two 24-in.-diameter cylinders operate a pair of brake shafts from which the power is transmitted to the brake blocks by suitable rigging, and when the Westinghouse system is in use, the power is obtained from a 17-in. diameter cylinder. Further, the vacuum brake is fitted with a converter cock for use on certain sections. The Westinghouse brake is fitted with a double pipe line so that the system may be either automatic or controlled. The same brake rigging can be operated by hand from a wheel placed in the vestibule at one end of each car.

The cars were built at the Leeds Forge Company in England and their transportation to the coast and shipping them to France presented a difficult problem. It was, however, arranged to have the cars travel to the port of shipment on their own wheels complete, excepting for the removal of a few parts of minor importance. There it was found that the Channel ferry steamers built during the war for the purpose of carrying rolling stock to the Continent were available.

It was found necessary, however, to construct the new terminal at Immingham, where these cars could be loaded on to the boats. The problem of loading was not an easy one either and, for example, ramps were provided over which the cars were run on to the ferry-boat deck direct from the quay, an ingenious arrangement having been installed to allow for the rise and fall in the dock water level to prevent delay in loading owing to tidal conditions. (*Railway Review*, vol. 72, no. 1, Jan. 6, 1923, pp. 63–67, 8 figs., *d*)

REFRIGERATION (See also Special Machinery)

Comparative Ammonia Condenser Reports, P. Wilson Evans. For a number of years Armour & Co. have compiled a weekly comparative statement showing data on ammonia condensing for their principal plants. By means of these reports it has been possible to deduct and remedy inefficient operating conditions with a resulting saving in power and operating expense. A copy of one such report is given in the article here abstracted.

One of the columns of this report shows a total excess pressure over ideal conditions. It is the endeavor to hold this total excess pressure down to not over 25 lb., but it is difficult to accomplish this. It is only by keeping constantly after this phase of operation that this excess pressure is kept from going considerably higher. The red pencil marks on the copies of the reports sent to the different plants indicate whether the condenser should be purged or other steps taken to reduce the pressure.

In case a plant is found to be materially out of line in its condenser pressure the question always arises as to how much of a loss in dollars and cents this condition is causing. Cases have arisen where the total excess pressure has been as great as 80 lb.

The original article presents a chart showing the horsepower required to compress adiabatically the ammonia required to produce one ton of refrigeration, assuming the suction gas dry and saturated. The curves of the chart were calculated by the author and are plotted with horsepowers per ton as ordinates and absolute suction pressures in pounds per square inch as abscissas.

From an analysis of the figures as reported in one of the weekly comparisons it would appear that in many cases purging of the condenser is necessary to reduce the excess pressure present, and the author shows how materially a reduction of excess pressure affects the cost of operation.

While there is a well-grounded prejudice against too much condenser purging on account of the possibility of excessive ammonia loss, actually the amount of this loss depends largely upon the care taken in purging. In the author's opinion the most satisfactory method of purging an ammonia compressor is to shut it down and allow water to flow over it until there is no material difference between the temperature of the water going on and coming off. Then observe this water temperature and find from the ammonia table the corresponding condenser pressure. This pressure represents accurately the vapor pressure of the liquid ammonia in the condenser and if the gage on the condenser shows higher pressure, the excess is due to non-condensable gases such as air. The purging should be discontinued at a point somewhat above the pressure corresponding to the water temperature, thus assuring that there will be no great amount of boiling off of liquid ammonia.

The difficulty in purging below the pressure corresponding to that of the ammonia vapor at a specific temperature is to know just when to discontinue it, but this is due to excessive pressure of non-condensable gases assumed in this case. Under more normal conditions it is satisfactory to discontinue the purging just at or slightly above the ammonia vapor pressure corresponding to the temperature of the water flowing over the condenser. If this is done, the loss of ammonia at all times will be insignificant. Or-

dinarily, it is considered better practice to purge several times in this manner than to continue the purging to a lower pressure. (*Power*, vol. 57, no. 1, Jan. 2, 1923, pp. 28–30, 1 fig., *dp*)

RESEARCH (See Engineering Materials)

SPECIAL MACHINERY

Vapor Recompression System for Evaporators. Discussion of regenerative evaporation, with comparison of operative economies with single and multiple-effect evaporators. A bibliography of patents and literature is appended.

The nozzle systems are considered to be the easiest to discuss qualitatively. For high efficiency it is necessary to work with a small temperature drop and very high-pressure steam. To get double-effect efficiency (1 lb. of vapor entrained per pound high-pressure steam), the total temperature drop may not be over 18 deg. fahr. for 100-lb. steam, 22 deg. fahr. for 150-lb. steam, or 22.5 deg. fahr. for 175-lb. steam. Ordinarily evaporators are designed to operate with from 5- to 15-lb. steam. If a single-effect evaporator with a nozzle compressor be compared with a double working between 10 lb. and 26 in. vacuum, it will be found that the double has a total available temperature drop of 100 deg. fahr. against, say, 20 deg. for the other. Hence, on material of no elevation in boiling point the double would have five times the capacity of the single, twice the heating surface, and would require the same amount of steam condensing water and accessories.

The comparison used is more strongly in favor of the double when the plant has exhaust steam to spare, as then the double saves either all the high-pressure steam used in the nozzle (if exhaust steam is available, which otherwise would be wasted) or it saves all the condensing equipment and condensing water otherwise needed for the prime movers.

The best use for the nozzle is the plant where all exhaust from prime movers is used in the evaporators and in addition make-up has to be supplied as live steam. A nozzle may be substituted for the usual reducing valve on the make-up steam line; provided, of course, that the evaporator in question is a multiple effect with a small enough temperature drop in the first effect to make the nozzle efficiency appreciable. Here again attention must be paid to the rapidly decreasing efficiency of the nozzle as the steam pressure drops; because if the amount of make-up needed is variable, the nozzle will give useful results only when the throttle valve is wide open. Under conditions demanding less than the maximum amount of make-up steam, its capacity will be negligible.

It has been suggested by Claassen that several small nozzles in parallel be cut in or cut out one at a time as the demand for make-up varies, but each to be either completely closed or wide open and never throttled.

The remainder of the article, though of considerable interest, cannot be abstracted here owing to lack of space. It is devoted to an extensive discussion dealing with the selection of the type of evaporation equipment as affected by the method of power generation at the plant either available or to be installed. A bibliography on vapor-recompression systems for evaporators, and, to some extent, evaporation generally, is appended. (*Chemical and Metallurgical Engineering*, vol. 28, no. 2, January 10, 1923, pp. 73–78, *gcA*)

Oxygen Enrichment of Blast in Blast Furnaces

Oxygen-Enriching, Superheating, and Drying of the Blast. The question of enriching the blast in oxygen is now the subject of an investigation by the U. S. Bureau of Mines. It is of interest to mechanical engineers as the majority of the methods now known to accomplish this purpose involve the use of compressor and low-temperature refrigeration equipment.

In a paper before the Liége Congress M. Derclave, as regards enriching the blast in oxygen, arrives at the following conclusions: The addition of 5 per cent (in volume) of oxygen does not improve the working of a blast furnace upon the whole, because the advantages gained in respect of coke consumption are lost by the reduced calorific value of the furnace gas. Any further increase in the oxygen content would have no effect, because the limit of the indirect reducing power of the gas has almost been reached, the ideal limit, according to Gruner, being reached when $m = 1.21$ is raised to 1.57—that is, when the whole of the oxygen in the burden is abstracted by the CO. This condition is, of course, impossible to attain so long as there is any water vapor in the flowing gas, as must be the case when damp and chemically hydrated ores are used, like minette. The 5 per cent to 6 per cent in volume of oxygen added must be considered the limit beyond which the point of equilibrium is approached, at which the quantity of CO required at the tuyeres for fusing the materials is equal to that necessary for the complete reduction of the charge by the gas. Beyond this point no further increase in efficiency can be realized in blast-furnace working. One has reached the most favorable conditions for the indirect reduction by CO, which is the essence of successful blast-furnace working, as shown by the equation:

$$Fe_2O_3 + 6\,CO = 2\,Fe + 3\,CO_2 + 3\,CO \ldots\ldots\ldots \quad [1]$$

for which the ratio CO_2 to CO in volume equals unity, or 1.57 in weight.

To obtain further economy in fuel consumption it would be necessary to oxidize the carbon directly by the oxygen in the ore, and to find some other apparatus than the furnace which would realize the reaction represented by the equation:

$$Fe_2O_3 + 2\,C = 2\,Fe + CO_2 + CO \ldots\ldots\ldots\ldots\ldots \quad [2]$$

which shows that carbon utilized in this direct way would give a reduction three times greater than when burned at the tuyeres of a furnace by the air in the form of CO. Because, according to Equation [2], to reduce two units of iron, two units of carbon are required in the case of direct reduction, while by Equation [1], on the contrary, six units of carbon are required in the case of indirect reduction.

It is easy to calculate that to obtain 1000 kg. of iron containing 3.5 per cent C, by the indirect method, 35 kg. of C are required to carbonize the pig iron, a further 515 kg. to reduce the iron oxides indirectly, and 25 kg. for the direct reduction of the other oxides; thus a total of 575 kg. would be required for the fusion of the iron and the slag and the consequent separation of the metal from the gangue.

By direct reduction no more than 192 kg. of carbon would be required, but it would be necessary to draw upon other sources of heat to insure fusion. By utilizing methods of heating not entailing the combustion of carbon, such, for example, as heating, drying, or enriching the blast in oxygen or electrical heating, the whole of the carbon would be utilized for the reduction of the ores and not for smelting, and the saving in fuel would thus be pushed to its maximum.

There is, then, a comparatively narrow limit to the extent to which oxygen can be added to the blast. Even with the addition of 5 per cent in volume, that is 27 per cent of oxygen by weight, the limit is reached; for the high temperature reached at the base of the furnace would destroy the lining, while at the top of the furnace there would be a rapid falling off in the reducing effect of the gas. As regards the hot blast, it, among other things, increases the ratio of CO_2 to CO in the furnace gas; that is, the ideal operation is more closely approached. The hotter the blast, the smaller will be the quantity of carbon consumed at the tuyeres, and consequently the volume of CO produced in that region will be reduced. Since the oxygen content of the ore remains the same, the proportion of CO_2 will increase and the ideal ratio of CO_2 to $CO = 1$ (in volume) will be attained. The excess of CO_2 in the reduction zone will then act on the soil carbon, and, while the consumption of fuel is reduced in the region of the tuyeres, it is increased in the reduction zone. The final result will be that there will be a notable reduction in fuel consumption without affecting the quality of the product. (Paper before the Liége Congress. Abstracted through *The Iron and Coal Trades Review*, vol. 106, no. 2863, Jan. 12, 1923, p. 53, *g*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general, *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Test Code for Internal-Combustion Engines

Preliminary Draft of Another Code in the Series of Nineteen Being Formulated by the A.S.M.E. Committee on Power Test Codes

The Power Test Codes Committee on Internal-Combustion Engines which developed this Code is headed by Dr. Charles E. Lucke as Chairman, the other members being Edward T. Adams, Harte Cooke, Max Rotter, and Arthur West.

The Committee and the Society will welcome suggestions for corrections to and modifications of this draft of its Code from those who are especially interested in the testing of Internal-Combustion Engines. These comments should be addressed to the Chairman of the Committee, in care of The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y.

Introduction

Tests for determining the performance of internal-combustion engines by this code apply to all forms of internal combustion engines, but are limited to the engines alone. Separately driven auxiliaries that are essential to the operation of the engine, such as scavenging pumps or blowers and injection air compressors, for example, must be included in the tests, but the testing of such units must follow the other codes appropriate to the unit to be tested and the results in horsepower absorbed introduced and used in this code.

2 Internal-combustion engines, compared to others for which codes are available, include a much greater variety in form, size, speed, weight, fuels and other operating conditions, with more or less special features for particular applications. This fact makes it necessary in a single inclusive code like this to leave many details of the test to the judgment of the test engineer, or to be made the subject of expressed agreement before the test is started. Suggestions are offered in this code as to limitations, alternatives and difficulties to aid in making selections of details, always with the understanding that suitability to the case shall be the basis of judgment.

3 Sizes of internal-combustion engines coming within this code range from one horsepower to several thousand. Speeds range from less than 100 r.p.m. to over 3000 r.p.m. Numbers of cylinders range from one to twelve or more; some horizontal and others vertical; some single-acting and others double-acting; some two-cycle and others four-cycle, with every variety of attached and separate scavenging pump for two-cycle engines. Fuels range from the lightest distillates to the heavy residue fuel oils, organic and mineral in the liquid-fuel class, and in the gaseous form include every combustible gas commercially available. Purpose and variety of load or other service conditions normal to and proper for each engine cover equally wide ranges. Stationary engines operate at all loads normally at constant speed under governor control, for any period of time and any degree of intermittence of use. Marine engines operate normally at full load, and the constant speed fixed by the propeller, but must be maneuvered ahead and astern at any speed under hand control, and may operate for any period of time from short intermittent runs to the continuous full load for a month or more required of seagoing motorships. Aircraft engines must meet about the same service conditions as marine engines, except that a smaller length of single run is required, but they must operate in the greatest known ranges of atmospheric pressure and of temperature. Other engines of the automotive group, those for land transportation, including those for automobiles, motor trucks, tractors, railroad locomotives and self-contained cars, are essentially variable in speed as normally used, and equally variable in torque, horsepower being as much a matter of secondary importance as in a hoisting engine or steam locomotive. The engines of this last group drive their vehicles through gear sets of different speed ratios, at changing vehicle speeds and changing vehicle resistance, and tests of them must be conducted with due regard to these service conditions.

It is obviously impossible in any single code to prescribe tests in detail that could be equally applicable to all these conditions, so that some exclusions are necessary. At the same time it is highly desirable that tests for all internal-combustion engines set by this code should have as much in common as may be possible, even if some latitude of judgment is necessary to make this possible.

4 Excluded from this code are the following:

(*a*) Complete internal-combustion engine stationary power plants using gaseous or liquid fuels, which have power-generating or power-absorbing auxiliaries separate from the engine
(*b*) Motor-boat and motorship power plants and the vessels themselves
(*c*) Aircraft and their power plants
(*d*) Land propelled vehicles, with or without speed-change gears, including motorcycles, automobiles, motor trucks, tractors and rail locomotives or self-contained cars
(*e*) All internal-combustion engine "sets," consisting of an internal-combustion engine so combined with a driven unit as to make it impossible to separately determine the performance of the engine itself, or such as falls within the scope of other codes, excepting only electric generating sets. Among these sets herein excluded are internal-combustion-engine pumps, compressors and hoisting outfits, whether used for hoisting or for hauling
(*f*) All internal-combustion engines, the construction or operating conditions of which prevent an output determination in terms of either brake horsepower or kilowatts, for a generating set.

5 Included within this code are the following internal-combustion engines not excluded by any of the items of Par. 4:

(*a*) Stationary engines, and electric-generating sets even if not intended for stationary use, burning gaseous or liquid fuels, including the scavenging pumps of two-cycle engines, and injection air compressors, if used and separately driven
(*b*) Marine engines exclusive of propeller, and burning light or heavy liquid fuels
(*c*) Aircraft engines limited to block tests, exclusive of propeller, and burning light liquid fuels
(*d*) Land vehicle engines limited to block tests and burning light and heavy fuels.

6 Reference is made, in connection with the exclusions of Par. 4, to the separate codes for testing:

(*a*) Displacement Pumps
(*b*) Centrifugal and Rotary Pumps
(*c*) Reciprocating Displacement Compressors and Blowers
(*d*) Centrifugal and Turbo-Compressors and Blowers
(*e*) Refrigerating Machines and Plants
(*f*) Locomotives.

Reference is also made in general to other codes prescribing items forming part of this code, which must be considered in connection with it. All directions in these codes, noted below, applicable to this one must be followed:

(*g*) General Instructions
(*h*) Definitions and Values
(*i*) Instruments and Apparatus
(*j*) Fuels.

Object

7 In accordance with the "General Instructions," the object of the test, and if more than one, then each separately, should be determined and recorded.

This code is limited to tests in which the object is of a commercial nature. It excludes all tests forming part of experimental investigations, research or development. But while no engineer undertaking tests of a research or development nature needs any code if he is competent to make such investigations, it will usually be found that parts of such research work will be aided and in no way hampered by following parts of this code. It is also in the interests of those branches of engineering, whose progress is based on experimental data, if any parts of an investigation are carried out in accordance with the code, and recorded in accordance with the code. Results so obtained are more easily comparable with the large numbers of tests always being carried out on the lines of the code. The research data then enter readily into the general body of knowledge of the internal-combustion engine.

8 Tests of the kind contemplated by this code and for which it has been prepared, are those in which the object of the test is *definition* of an engine by its performance characteristics.

9 When the object of the test is wholly or in part the determina-

tion of fulfillment of a contract guarantee, an agreement should be made before the test between the interested parties on all matters that involve any possible elements of uncertainty, or that may later be a cause of dispute, as noted in Par. 3 of the "General Instructions," and the points agreed upon should be stated in the report of the test.

10 Agreements between interested parties should also be made and recorded even when a contract guarantee is not involved, before undertaking any test in which an element of judgment is involved in the selection of any instrument, piece of apparatus, physical constant, test method, operation condition or other matter that will promote the accuracy, the value, conclusiveness or the general acceptability of the results when obtained. This matter is one of special importance in tests on internal-combustion engines because of their great variety.

11 Sub-objects of the main object may often be of value in improving the value of results obtained in the test for the main object and may themselves be made the subject of separate tests, but in all cases *only* when made the subject of previous agreement as to the nature of the sub-objects and the test procedure. Sub-objects of a test must be separately reported as such to clearly distinguish them from the main object, and it is advisable that reasons be given for making such special tests. This is especially important when the special test for the sub-object is to be conducted at the same time as the test for the main object. Some sub-objects that may be expected to arise in connection with code tests of internal-combustion engines are listed below, but no special instructions concerning them are included in this code. Selection is left entirely to the judgment and agreement of the test engineers, but none of these sub-objects will be considered as tests made "according to the A.S.M.E. code," unless specifically added to the requirements by agreement and so marked in the report. It is recommended as good practice that they conform as far as possible to such parts of this and other codes as may be found applicable, especially those enumerated in Par. 6.

(*a*) Exhaust-gas analysis, with special reference to the determination of air not utilized by the engine in combustion, and of unburned fuel or combustible
(*b*) Exhaust-gas temperature, with special precaution to get accurate results in view of high velocity of gases, intermittent flow, and cooling conditions in exhaust ports and pipes, determined with special reference to equalization of load between cylinders of multi-cylinder engines, or accuracy of adjustment of combustion conditions, or percentage of fuel heat discharged in the exhaust
(*c*) Amount of air taken into an engine, with special reference to the volumetric efficiency and the completeness or incompleteness of the charging as a factor in actual as compared to possible power developed
(*d*) Properties of liquid or gaseous fuels with reference to suitability for use in the engine, or with reference to identity of the fuel as to some specification
(*e*) Determination of variations in the quality of lubricating oil or its contamination by use, especially by fuel or fuel products, and particularly for engines provided with a fixed amount of lubricant successively reused
(*f*) Nature of solid deposits in combustion chambers, on pistons, valves and ports, resulting from use and originating in fuel or lubricant or in solids carried by the air
(*g*) Amount of air required to start an engine provided with air-starting equipment, in relation to the capacity of starting compressors, especially for engines that must be frequently maneuvered in service
(*h*) Electrical starting requirements of engines using electricity for starting on heaters or electric motors, in relation to generator and storage battery
(*i*) Amount and pressure of air required for air-spraying apparatus of air-injection oil engines using fuel oils, in relation to the spray-air compressor capacity
(*j*) Power consumed by each or all of normally attached auxiliaries, with or without other operative characteristics of these auxiliaries, which include electric generators or magnetos, storage batteries or complete electric ignition apparatus, jacket-circulating pumps, direct or radiator cooling fans, lubricating-oil and fuel-oil pumps, starting and spray-air compressors, scavenging pumps of two-cycle engines, attached fuel and lubricating-oil heaters and coolers
(*k*) Smoke quantity and color or density, and particularly when smokelessness in some degree is a matter of importance or of specification.

Measurements

12 The measurements that must be made in a performance test of an internal-combustion engine will be the following quantities:

(*a*) Cylinder diameter, stroke and clearance volume of working cylinders.
(*b*) Diameters of piston rods and tail rods of working cylinders of double-acting engines
(*c*) The brake-horsepower or shaft-horsepower output
(*d*) The kilowatt output if engine is direct-connected to a generator
(*e*) The speed in revolutions per minute
(*f*) The horsepower to drive the water-cooling pump and fuel-pump (if any)
(*g*) The horsepower to drive the independent scavenging pump or blower
(*h*) The horsepower to drive the independent injection air compressor
(*i*) The amount of fuel supplied: cubic feet of gas for gas-burning engines, or pounds of liquid fuel for liquid-fuel engines. If more than one kind at the same time, the amount of each kind
(*j*) The calorific value of the fuel, high value.

13 The measurements which may be made in addition to those required by Par. 12, will be some or all of the following as may be agreed in advance by the test engineers:

(*a*) Cylinder diameters and strokes of injection air compressor
(*b*) Two-cycle engine scavenging pump diameter and stroke
(*c*) Diameters of piston and tail rods of scavenging pumps of two-cycle engines
(*d*) Diameters of piston rods and tail rods of injection air compressor
(*e*) The indicated horsepower
(*f*) The number of explosions per minute, or fuel injections per minute, or in general, combustion times per minute, for each and for all working cylinders
(*g*) The spray-air pressure of air-injection oil engines
(*h*) The exhaust back pressure at the engine
(*i*) The scavenging-air pressure of two-cycle engines, constant or maximum values
(*j*) The manifold vacuum of carburetor engines
(*k*) The jacket-water or oil-supply pressure at the main, and if jackets are divided with separate supplies, the pressure at the supply point or branch pipe to each
(*l*) The jacket water or oil back pressure at the main outlet, or if jackets are divided with separate discharges, the pressure at the outlet of each
(*m*) The pressure or vacuum or the hydraulic head, positive or negative of the supply of liquid fuel at the carburetor connection of carburetor engines, and at the injection-pump suction of injection oil engines
(*n*) The pressure or vacuum of the gas supplied to gas-burning engines at the mixing valve connection
(*o*) The total pressure, static and velocity of cooling-air supply of air-cooled engines
(*p*) Barometric pressure
(*q*) Atmospheric humidity
(*r*) The pressure of lubricating-oil supply to bearings of engines lubricated by pump forced-feed circulation
(*s*) The temperature of the atmospheric-air supply
(*t*) The temperature of the fuel for gas at the mixing valve, or for liquid fuel at the carburetor or injection-pump suction
(*u*) The temperature of the jacket water or oil as supplied to the engine as a whole, or if jackets are divided with separate supplies, the temperature of each separate supply
(*v*) The temperature of the jacket water or oil leaving the engine as a whole, or if jackets are divided with separate outlets, the temperature at each outlet
(*w*) The temperature of the scavenging air of two-cycle engines
(*x*) Temperature of injection air
(*y*) The temperature of the lubricating oil supplied to the engine at as many points as there are different supplies of pump-circulated lubricating oil, or in the crankcase of engines without pumps or having pump deliveries that do not permit of temperature measurement
(*z*) The temperature of the cooling air supplied to an air-cooled engine
(*aa*) The amount of lubricant consumed, pounds
(*ab*) The amount of jacket water or oil supplied, pounds, for engines as a whole, and when jackets are divided for each if both supply and discharge are separate
(*ac*) Amount, pounds or cubic feet, of cooling air supplied to air-cooled engines
(*ad*) Amount, pounds, of jacket water evaporated in jackets of hopper-cooled engines
(*ae*) Amount, pounds, of injection water supplied internally to cylinders of some oil engines, as a liquid or as steam
(*af*) The compression pressure in cylinders when hot and cold, at normal or at reduced speed at wide-open throttle.

14 In preparing a list of measurements from the items of Pars. 12 and 13, to be made preparatory to the planning of the log, and as a guide to their selection, it must be noted that in the above lists of measurements there are provisions for three groups:

(*a*) Measurements required for the determination of results required for this code, namely, those of Par. 12.
(*b*) Measurements to indicate the maintenance or variation of important operating conditions which might be described as the steady state required for the test prescribed, but which measurements do not themselves enter into the results except as specifying conditions under which the results were obtained. For example,

this is the case with all jacket water or oil and all lubricating-oil measurements of pressure, temperature and quantity. These are included in the list of Par. 13.

(c) Measurements for one or more of the determinations required by such sub-objects listed in Par. 11, as may be made the subject of an agreement by the interested parties. These are included in the list of Par. 13.

Instruments and Apparatus

15 Directions regarding the application, use and calibration of instruments and apparatus, do not form part of this code. Such information is given in the Code on Instruments and Apparatus, supplemented by that on Definitions and Values, in which will also be found statements on scope and limitations of use, and on accuracy.

The instruments and apparatus required for a performance test of an internal-combustion engine as prescribed by this code will include some or all of the following:

(a) Scales with or without special auxiliary apparatus for weighing liquid fuel, with or without tanks to be used in coöperation
(b) Gas meters for measuring gaseous fuel, or gas-metering methods with indirect observation apparatus
(c) Gas calorimeters for determining the heating value of gaseous fuels
(d) Baumé oil hydrometer for petroleum liquid fuels, and for indirect determination of calorific power
(e) Pressure gages and mercury or water columns for measuring small pressures and vacua
(f) Thermometers
(g) Barometers
(h) Gas-engine and oil-engine indicators for working cylinders and steam-engine indicators or special low-scale springs for cylinders of two-cycle scavenging pumps and low-pressure cylinders of injection air compressors
(i) Pressure-indicating or recording instruments for compression pressures or injection pressures in cylinders
(j) Planimeters
(k) Tachometers, revolution counters or other apparatus for measuring speed or number of fuel admissions per minute
(l) Absorption dynamometers of appropriate type for the horsepower, speed and torque of the engine to be tested, especially hydraulic brakes and electric dynamometers
(m) Appropriate electrical instruments and apparatus, if the engine is direct connected to a generator, to provide a suitable electrical load and to measure it.

16 In making a selection of instruments suitable for the measurement of quantities required by the performance test under this code, and constituting its main object per Pars. 7 and 8, it is necessary to exercise considerable latitude of judgment in view of the variety of internal-combustion engines noted in Par. 3, to insure proper relation of selected instrument to the conditions of measurement to be made. Some suggestions are offered below as a partial guide to such selection.

17 Indicators cannot be used at all on some internal-combustion engines and in other cases only within limits. In no case can an indicator be regarded as a precision instrument on an internal-combustion engine to the same degree as on a reciprocating steam engine. Some special cases are noted:

(a) When the engine speed exceeds 400 r.p.m. an indicator must not be used for determining the cylinder mean effective pressure of an internal-combustion engine. This excludes it and the determination of indicated horsepower for all engines of Par. 5(c) and 5(d), and all engines of Pars. 5(a) and 5(b) operating over 400 r.p.m.
(b) When the engine speed exceeds 400 r.p.m. optical indicators may be useful as a means of adjustment of valve or spark timing, but have no other value, and are of no use even for such adjustments in the case of multi-cylinder engines
(c) On all hit-and-miss-governed engines the indicator must not be used for determination of the cylinder mean effective pressure for indicated-horsepower determinations, thus excluding such determinations from tests of hit-and-miss-governed engines
(d) When indicator cards taken even at speeds of 400 r.p.m. or less are not constant in shape and area over long periods of time while a constant load is maintained, the indicator must be rejected as a means of determining cylinder mean effective pressures though it may be used as a means of adjustment of timing, especially as a guide to equalizing the timing for multi-cylinder engines or the two ends of a double-acting cylinder. The test as to constancy of area shall be ± 2 per cent, so that when the largest area differs from the smallest area by 4 per cent or more of their arithmetical mean, all shall be rejected. At various odd intervals of time, at least ten diagrams shall be taken on one card in addition to those taken at regular intervals, for comparison as to constancy
(e) When indicator cards taken even at speeds of 400 r.p.m. or less are apparently constant in area, according to the conditions (d), they may still be useless as a means of determining cylinder mean effective pressure and indicated horsepower, when the cylinder pressures are very high, the spring scale large, 500 lb. more or less, and the whole measured card area at the same time is very small. Under these conditions the precision will be very low and the indicated horsepower much in error. Just what set of conditions will produce a result bad enough to reject must be left to the judgment of the test engineer, with the suggestion that the accuracy of planimetering the smaller area be used as a basis of judgment. This condition makes it hopeless to undertake determinations of indicated horsepower for many oil engines of the high-pressure type, developing only small mean effective pressures
(f) Even in the cases where the indicator cannot properly be used as an instrument for measuring mean cylinder pressures and indicated horsepower, it can be usefully employed as a means of adjusting and equalizing the cylinder compression, the adjustment of main valves, the point of ignition in electrically ignited engines, of spray-valve timing of Diesel oil engine, or the injection-pump timing of injection oil engines with direct pump injection
(g) When the conditions of proper use of indicators for mean-effective-pressure determinations are all fulfilled, no indicated-horsepower determination shall be made unless a separate indicator is used on each working cylinder of a multicylinder engine (each end).

18 Brakes or absorption dynamometers when used must be suitable for the engine to be tested, in capacity, in speed-torque relations, and in ability to maintain an adjustment without necessity for constant hand manipulation to hold scale beam steady.

(a) For testing all engines of Par. 5(c) and (d), nothing but an electric dynamometer shall be used to determine brake horsepower
(b) For brake-horsepower tests of engines of Par. 5(b), the electric dynamometer shall be used, or hydraulic, if reversing tests are to be run. On engines of this class of large size and lower speed, hydraulic brakes of the type in which brake torque varies with the nth power of the speed, and in which n is equal to or greater than 1.5, shall be used as the preferred form.
(c) Other forms of brake may be properly used with engines of Par. 5(a) and so also when available may the hydraulic type and the electric dynamometers above described
(d) When brakes of any kind cannot be mounted directly on the engine shaft without other supports, due precautions must be taken, per instructions in the Code on Instruments and Apparatus, to avoid errors due to these supports
(e) In no case may a brake driven by a belt or otherwise than by direct coupling to or mounting on the engine shaft, be used for engine brake-horsepower measurements
(f) With due precautions and under proper provisions brake-horsepower determinations may be made by the indirect or substitution method, and this is important because in some cases it is the only means available. According to this method the engine may be tested with a load such as a propeller (air or water type), a club or a fan, which propeller or fan may later be, or previously have been, tested for its speed-torque characteristic curve, and the horsepower of the engine determined by reading from this curve the horsepower for the speed maintained by the engine. The special precautions referred to relate to assurances of identity of conditions of flow through and resistance of the propeller or the fan under the two separate tests of use and of calibration. This is so difficult that none but test engineers of special experience should undertake it. In no case can results of test-stand torque alone be acceptable in brake-horsepower determinations for an engine.

19 In measuring speed, the choice of instruments is determined by the character of the test carried out. Continuous speed counters may be used only for slow-running engines, where a constant speed of considerable duration is maintained. Hand speed counters placed directly against the engine shaft may be used, if handled carefully and well made. Tachometers may be used of the centrifugal, liquid pumping, or magnetic type, but these must be carefully calibrated and records of recent calibration must be available. Tachometers must be connected by a reliable tachometer shaft or by positive gearing to the engine shaft, and in no case should belting be used as a connecting link.

20 The heating value of fuels to be used in calculations of results of tests of internal-combustion engines must be the "high value" products condensed or the direct reading of a water calorimeter properly used in accordance with the procedure specified by the Code on Fuels.

Accordingly the following recommendations are made:

(a) When gaseous fuel is burned in an engine under test, a standard form of gas calorimeter shall be used as one of the instruments of the test, and its determination shall be used as the heating value of the gas as supplied. Calculations of heating value from the gas analysis are not permissible according to the code, but with all details of apparatus, methods and physical constants involved may be made the subject of previous agreement
(b) When liquid fuel is burned in an engine under test, its heating value shall be determined in a standard bomb calorimeter by a recognized physical or chemical laboratory, the selection of which

should be a matter of previous agreement, and in the report the "high value" should be used in calculating final results. In no case shall such a determination be part of the duty of a test engineer, nor should his results be regarded as acceptable

(c) The heating value of gasolines and kerosenes may be estimated by the Sherman & Kropff formula, modified by Strong, from the Bé. reading without the bomb test, if such procedure is made the subject of previous agreement.

21 Gas measurements for engine burning gaseous fuel must be made with meters or by methods yielding the greatest possible accuracy consistent with availability and cost in the large sizes.

In no case can the results of proportional meters be regarded as satisfactory, nor those of vane meters of the anemometer type. Within the limits of size and cost, positive displacement meters are to be preferred, but these are not available for measurements of large capacity.

Large capacity measurements are best made by means of one of the various types of flow-rate measurements, and that one, applied to mixed gases, should be used that requires the simplest and most accurate determination of physical or chemical properties.

When physical or chemical properties of a mixed gas must be determined for use in a metering calculation, even if only gas density direct or computed from the analysis, a recognized chemical laboratory shall be agreed upon to make the determination and its report shall be accepted and used. In no case shall the test engineer make a determination of physical or chemical properties of gases, nor shall his results be acceptable if he does so.

If measurements of volume of injection air or of scavenging air are desired, the orifice-flow method will be sufficiently correct if used as prescribed in the Code on Instruments and Apparatus, but the formula and conditions for such test must be agreed upon in advance between the engineers.

22 Liquid fuel supplied to an engine should never be measured by volume; it must be weighed directly as used. Combinations of weighing and volume measurements are acceptable if the volume of the tank itself is not the measure but only a reservoir from which the engine draws a supply, starting with a predetermined level marked by a hook gage or on a glass, and a weighed quantity subsequently supplied to restore the original level. In this case the weight is the measure and the result acceptable if proper precautions are used to limit the weight error of reading levels to something less than the error of the scale weighing.

In no case shall meters be used to measure liquid fuel supplied to an engine.

When volatile fuels are used, and especially when heavy liquid fuels containing light volatiles must be heated to make them flow, precautions must be taken to prevent losses of weighed fuel by evaporation, and the main supply must be protected against evaporation that may fractionate or concentrate it and change its quality with time.

Preparations

23 Before proceeding with a test, Pars. 4 to 8 of the "General Instructions" should be reviewed. The dimensions and physical conditions of all parts of the engine should be determined and recorded. The same should be done for all parts external to the engine to be tested, the condition of which might effect the success of the test in many ways.

24 Things external to the engine should always be given attention first, and if on inspection and preliminary trial anything should be found that might impair the value of the test, it should be corrected before starting or even before the condition of the engine is examined. In view of the great variety of engines and operating arrangements, it is impossible to enumerate all of these things, but for their suggestive value a few are noted below:

(a) Jacket-water supply should be assured in proper quantity, of proper cleanliness as to freedom from sediment, non-corrosive, and of a kind that will not deposit scale in the jackets when its temperature is raised. It is necessary also to arrange for as nearly constant a supply temperature as possible to maintain a steady state as to temperature of heated engine parts. The exceptions to this are: air-cooled engines; engines with boiling hopper jackets or with thermosiphon circulation to tanks, or with any sort of circulation of a fixed amount of water between jackets and a radiator or cooler. In these cases a proper supply of cooling water or air for the cooler or radiator must be assured. Engines operating with oil in jackets are included in the last group. Air-cooled engines must be assured of a supply of cooling air proper in amount, velocity and direction as well as temperature

(b) Engines operating with electric ignition, especially in the larger sizes, may be dependent on an external supply of current for the ignition system, or especially in small engines be supplied from primary or storage batteries. Assurance of continued supply at proper voltage for the whole test must be provided, and the most reliable means is an alternate source

(c) When liquid fuel is to be used, there should be a sufficiently large supply of the grade to be burned to last for the whole period of the test, and in the case of viscous or semi-viscous oils, which do not mix well without heating, special care should be taken to assure the mixing of new oil supplied to the tanks with that already in the tanks. This is especially important for that group of oil engines most sensitive to grade of oil

(d) Lubricating oil in sufficient quantities to complete the test should also be available before starting. When the lubricating system includes a tank or sump, especially when it is of considerable capacity, this should be drained and new oil provided or new oil in sufficient quantities properly mixed with it to prevent any changes during the test, other than those normal and incident to its operation.

25 If the engine is by previous agreement to be tested "as is," or in whatever condition it may happen to be, there is nothing further to be done before starting the test except to determine all those dimensions required to identify the engine, or necessary for the calculation of results.

On the other hand, and normally, the engine should first be put in proper condition to perform in a manner proper and normal to it, so that the test results will be not only a measure of what it did do, but also of what it is capable of doing.

In the absence of any agreement to the contrary, it will always be assumed that before starting the test the engine will be put in proper condition so far as can be done by cleaning, by stoppage of all leaks and by adjustment, including replacement of small parts, such as spark plugs or spray valves. Some suggestions are given as a guide to these several groups of items, but these must not be regarded as a substitute for the judgment of the test engineer, who should in all cases record not only the condition in which the equipment was found, but also everything done to change the condition.

26 Dimensions and other data not necessary for calculating test results but useful to identify an engine or to increase the value of future comparative analyses may properly include some items of its commercial specifications not properly classifiable as dimensions. Among such items, including some that are necessary for calculating test result, are:

(a) Bore, stroke, number of working cylinders and in the case of two-cycle engines, the same information for scavenging pumps, with notes as to single- or double-acting arrangement for either or both and notes regarding injection air compressor if used

(b) Dimensions of other principal fixed and running parts, diameter and length of all important bearings and pins, including piston rods and tail rods

(c) Dimensions of certain minor parts, fixed and running parts having important functions, such as valve lift, port area, area through mixing valves of gas-burning engines, carburetor choke area and nozzle sizes, injection-pump plunger bore and stroke, push-rod or valve-rocker clearances

(d) All items of adjustment and timing and for each cylinder of multi-cylinder engines such as spark of electric ignition engines, spray valve of injection oil engines when mechanically operated, opening and closing angles, injection pumps of injection engines delivering directly to spray valves not mechanically operated, start and stop angles, normal pump by-pass valve, timing of injection oil engines, inlet and exhaust valves of four-cycle engines opening and closing, all special valves of two-cycle engines

(e) All nameplate information, together with important identification items of specifications especially concerning attached auxiliaries, nature, size, capacities, with proper working pressures, temperatures or other items of operation or adjustment

(f) Certain dimensions in addition to the above, not matters of identity nor necessary for calculation of test results but of importance in judging the condition of the engine as a machine and useful in judging the value of the results of the test. Here are included all items of alignment, clearances of bearings, pins, rods and slides, pistons in cylinders, rings in grooves, valve stems in guides, pump plungers in pump body, throttle in seat, together with variations from straightness or roundness of cylinders, pistons and other parts.

27 Cleanliness, especially internal, is of great importance in the operation of internal-combustion engines. Attention should be given, among other things, to the following suggestions:

(a) Jacket surfaces on the heat-receiving side must be free from water scale, rust or other deposits, including carbonized oil, if oil is used

in place of water. Any deposit will cause the engine to operate unduly hot and may prevent operation entirely

(b) Combustion-chamber walls, including piston heads and all inward-facing parts, such as spark plugs, spray valves, air starting valves, relief valves, as well as inlet and exhaust valves and the ports of four-cycle engines, and the ports of two-cycle engines, should be free from deposits, especially carbon, oil, gum or tar, and solids derived from uncleaned air. This also applies to cylinder walls and piston rings

(c) The lubricating-oil system should be free of all deposits of whatever kind, and all flow passages freely and fully open, especially with circulating forced-feed systems

(d) The exhaust system, including expansion chambers, mufilers and pipes should be clean and free and so arranged as to not develop excessive back pressure. Other engines exhausting into the same system must not interfere with the engine under test. It is always preferable however that no other engines should exhaust into the system of the engine under test

(e) Fuel-supply and regulating systems must be clean and free of sediment, tar or other foreign matter, and passages fully open, especially for liquid-fuel engines, at the carburetor or injection pumps.

28 Leakages must be located and corrected. Among important leakages to be investigated attention is called to the following:

(a) Cylinder leakage outward, lowering the compression and efficiency or possibly preventing operation. These leakages may be best checked by an indicator if the engine is one suitable for indicator use. When there is any clear space between the compression and expansion lines of a card taken when there is no combustion and when cooling water is not running then it may be assumed that leakage is excessive. In this case, and in cases where an indicator cannot be used to check leakage, the several possible sources of such leakage must be separately checked. These are piston ring, cylinder, cylinder-head gasket, air starting valve, relief valve, spray valve or spark-plug seat, inlet or exhaust valves of four-cycle engines, or air scavenging valves of valve-scavenging two-cycle engines.

(b) Leakage into the cylinder may occur from the jackets through bad joints, cracks or porous spots and blowholes in the castings, compressed air from the starting air system through leaky air starting valves, fuel oil past spray valve at improper times and high-pressure spray air when air spraying is used in oil engines

(c) Miscellaneous leakages not into or out of the cylinder but elsewhere may be sought; in the manifold system of carburetor engines anywhere between carburetor and inlet-valve seat, especially at flanges and valve-stem guides; fuel oil in injection oil engines at pump valves, pump plunger, oil-delivery pipe or spray valve, lubricating oil at pump, tanks or in piping, spray air at compressor storage bottles, valves or piping, starting air at compressor storage reservoir, valves or piping. Insulation of electrical circuits must be checked as a leakage item.

29 Adjustments must be corrected if found to be wrong.

Operating Conditions

30 The operating conditions conforming to the object in view should prevail as pointed out in Par. 19 of the "General Instructions." If it is a matter of agreement that the engine is to be tested in whatever condition it may be, and under whatever conditions may prevail, then there is nothing to be done except to keep a record of all these conditions, with special emphasis on variations of every item that might effect the operation, or be useful in a subsequent effort to explain results.

On the other hand, if by agreement operating conditions are specified more or less completely, then instruments shall be used and observations made to establish their maintenance or variations.

In either case a record should be made and included in the final report.

This matter of operating conditions prevailing during the test is of very great importance in internal-combustion engines, not only because of their great variety and the corresponding variety of conditions normal to any one sort of engine, but also because the internal-combustion engine is self-contained, actually or essentially, and sensitive to many conditions within itself, not noticeable unless sought. Many of these have already been noted under "Preparations," as concerned with supplies, flows, leakages, clearances and fits or adjustments, but in addition to these there always arise questions of propriety of conditions of test in relation to conditions of service.

Doubt and confusion will always result in internal-combustion engine tests if any assumption is made to the effect that the conditions of test shall be "normal." If the word "normal" is used at all to describe the conditions, it must be defined by agreement. An agreement defining the conditions of the test is regarded as essential to all internal combustion engine tests. The definition should include all the items necessary in two groups noted below, one concerned with conditions in relation to service, and the other purely matters of test procedure.

31 Operating conditions to be maintained during the test are the ones most uncertain as will be clear from the following note:

Aircraft engines must normally work in altitudes varying from sea level to perhaps 30,000 ft., and in temperatures varying from highest in summer in the tropics, perhaps 120 deg. fahr., to the coldest known, under 50 deg. fahr. below zero, and in any weather—dry, fog clouds, rain and snow. They must also operate well at any angle of inclination and even upside down but always with an air-propeller load. In view of the fact that the only tests contemplated under this code are fixed block tests, it is clear that service conditions cannot be closely reproduced and only approximated even in the special altitude room of the Bureau of Standards with its air-refrigerating apparatus

Engines for land vehicles are essentially variable in speed and variable in load in normal operation, and must instantly respond to controls that are constantly and suddenly varied in heavy street traffic, or perhaps maintained for long periods of time in tractor or rail operation, and rarely develop maximum horsepower though frequently called upon for maximum torque. There can be no such thing as normal horsepower or speed for such engines and acceleration is quite as important as horsepower. They must, furthermore, operate on a fixed supply of jacket water or oil with an air-cooled radiator or directly air-cooled, so that external wall temperature varies not only with engine load but with vehicle speed, with weather and with climate.

As used, especially with tractors, the air supply is usually dirty, and may be heavily laden with gritty dust, requiring the use of more or less effective dust separators or air washers. Again, it is clear that service conditions cannot be maintained during the block tests contemplated by this code.

Marine engines, ranging from small single and multiple cylinder gasoline engines, often of very high speed, especially for racing boats with gear drives and clutches, to the direct-coupled large reversing low-speed Diesel oil engine of motorships of 2000–3000 hp., always with a propeller load, also operate under service conditions that cannot be reproduced in block tests.

Even stationary engines as a class while normally operating under conditions easier to reproduce in the block tests of tests in place according to this code, do also include considerable variety as to what is normal. Some of these, especially the smaller ones, such as farm engines or home lighting sets, operate for only short periods of time, and rarely if ever at full load. Others, especially those for irrigation pumping, may work continuously at the maximum possible load 24 hours per day for the irrigation period, of perhaps three months, and then be shut down for the rest of the year. Still others, especially those operating town water works or oil-pipe-line pumps may operate at full load 24 hours per day for a whole year or more. Still others, notably the generating units of central stations, must meet the widest and most sudden fluctuation of electrical load without varying in speed enough to affect voltage or synchronous operation of alternating-current systems.

The importance of agreement on these matters should be clear from these citations but the details must be left to the judgment of the test engineer.

32 Operating conditions during the test include mainly matters of load and speed to be maintained, with other points incidental to these. These should be agreed upon in all details, and should not be inconsistent with the conditions prescribed below:

(a) Engines of the stationary class, including all engine-driven generator sets, Par. 5(a), shall be tested at constant speed under governor control or as near constant as the governor will maintain it, and at whatever load in horsepower or kilowatts may be required by agreement or specific object of the test

(b) All engines for the propulsion of land vehicles, Par. 5(d), except such tractor engines as are fitted with speed governors and operate normally under governor control, shall be tested with throttle wide open, with brake torque regularly varied from nothing to a maximum and back to nothing, at whatever speeds may result, and the horsepower-speed curve typical of the engine shall be determined instead of the horsepower at any given speed. In no case should a *safe* speed be exceeded and when the highest speed used is the safe limit, it should be so stated. The maximum torque applied shall in all cases be greater than that which will produce maximum horsepower unless the speed required for this is too high to be safe

(c) Marine engines, Par. 5(b), and aircraft engines, Par. 5(c), may be tested according to the conditions prescribed for engines of land vehicles, in all respects according to conditions prescribed for stationary engines except that the speed shall be maintained by the brake torque and not by a governor. Marine engines may also be tested at constant speed for full-load operation fixed by their propellers.

Special attention should be given to questions of safety that may arise during operation, such as excess speed, or torsional vibrations at a given speed within the normal range, and the procedure to be adopted in such cases should also be included in the agreement.

Starting, Stopping and Duration

33 Before recording the test observations it is essential that an internal-combustion engine, together with all attachments and

appurtenances, be brought to a condition of *steady state.* The test cannot be considered as having started until the engine has been in operation for a sufficiently long time to have attained its steady state for the conditions of the first run, and until preliminary observations have been made and recorded to prove that such steady state has been reached. If successive runs are to be made, each under some different conditions, these must be repeated for each run.

The preliminary observations establishing the attainment of a steady state for the conditions of operation of the test or each run of the test, must be made a part of the record.

For an internal-combustion engine itself this is a matter of utmost importance, because the combustion chamber is a furnace in which heat is developed at a given rate, depending on the fuel burned per minute in each cylinder (or each end), and in which the metal temperatures vary with this rate of combustion. Metal temperatures vitally affect the performance of the engine especially those of cylinder, cylinder head, and piston, with all attached parts, and in addition those of all bearings.

The length of time necessary to establish the steady state will be different in engines of different class, and in any one class different for different sizes. In general, the weight of metal in contact with the combustion chamber directly or indirectly through thermal conduction will determine the length of time necessary, but the rate of combustion in B.t.u. per hour per square foot of cylinder area will also be a factor. The greater the metal weight and the lower the rate of combustion the larger the time necessary to reach the steady state. While jacket-water or oil temperatures are important factors, they are not the controlling ones. Lubricating-oil temperature in the sump or leaving the bearings in a circulating system, is a guide to steady state of both bearings and of combustion-chamber metal, but not a conclusive one. In no case shall an engine be regarded as having attained its steady state unless jacket and lubricating-oil temperatures are substantially constant.

The means whereby the attainment of the steady state is proved must be a matter of agreement, but the time of operation itself for the preliminary period may be substituted.

In no case shall steady state for the first run be regarded as established in a shorter time than one hour after the operating conditions have been imposed and before test observations have started. For successive runs at other conditions the minimum time for any engine shall be ten minutes, the actual time being determined by the extent to which conditions are changed in successive run. Maximum time to reach the steady state for any internal-combustion engine shall not be taken as greater than 24 hours, which may be regarded as permissible for the largest sizes of low-speed Diesel engines for motorships and double-acting stationary gas engines.

34 The duration of the test after the establishment of steady state for the set operating conditions shall be a matter of previous agreement, but should be greater for engines where reliability is a question of importance and which require the longest time to reach the steady state.

In no case shall the length of run be less than the period required to reach the steady state, subject to the additional condition that the length of run shall be great enough to insure the accuracy of fuel measurement within 1 per cent, except when gaseous fuel is metered and when metering accuracy is not improved by lengthened runs.

In some cases it may be found desirable to make a physical inspection of engine parts after the test to determine injury due to operation, but only when agreement has been made as to details should this be done.

Records

35 The general data should be recorded as pointed out in Pars. 20 to 30 of the "General Instructions." Instruments should be read at least quarter-hourly when the conditions are uniform, and oftener when there is much variation. Indicator cards, if taken, must be taken from every working cylinder of multi-cylinder engines. If there are wide fluctuations in readings, they should be shown by recording instruments.

Each indicator card should be marked when taken, with the number, date, time, scale of spring, number and kind of cylinder and end of cylinder, if double-acting.

The log should contain the records of the readings of all instruments, and these readings should be obtained at practically the same time as the indicator cards, if any, are taken.

If indicator cards are taken, the areas, lengths, mean effective pressures, compression pressures and maximum cylinder pressures, should all be recorded in the log. One or more sets of specimen indicator diagrams should be carefully selected for inclusion in the record. If, after taking indicator cards they are rejected, because of excessive fluctuation in area or insufficient area with high pressures for accuracy, a sample set of the rejected cards shall be included in the record with the data to support the rejection and justify the elimination of indicated horsepower from the results.

Calculation of Results

36 The calculations necessary for deriving results from observations or from physical constants should not be undertaken without previously consulting Pars. 31 to 35 of the "General Instructions," and the Code on Definitions and Values.

37 *Fuel Consumption.* For liquid-fuel engines the actual fuel measured is stated in pounds in the report of the test, and is subject to no corrections.

For gaseous-fuel engines the cubic feet of gas at whatever pressure and temperature prevailed, indicated or recorded by the meter or calculated from the reading flow-rate devices, is stated in the report of the test. This is to be corrected for the pressure and temperature at which the gas calorimeter burned the gas. The correction is to be made by multiplying the cubic feet of gas measured by the ratio of the absolute pressure at the meter to that at the calorimeter and by the ratio of the absolute temperature of the gas at the calorimeter to that at the gas meter. The product is the cubic feet of gas supplied to the engine measured at gas-calorimeter pressure and temperature.

38 *Heat Consumption.* The number of heat units consumed by an engine per hour is found by multiplying the consumption by the heating value. The heating value for gaseous fuels is stated in the report of the test as found by the gas calorimeter, in B.t.u. per cubic foot, high value. The heating value of liquid fuels is stated in the report of the physical or chemical laboratory engaged for the determination, in B.t.u. per pound of fuel, high value.

39 *Indicated Horsepower.* If indicated-horsepower determinations have been specified in the agreement before test and when the indicator can be used, and when in addition after using it the indicator cards are found to be acceptable as to accuracy for determining mean effective pressure, per Par. 16, then the indicated horsepower shall be calculated as follows:

For four-cycle engines the indicated horsepower for each single-acting cylinder and for each end of each double-acting cylinder shall be found by using the formula—

$$\text{I.hp.} = \frac{PLAN}{2 \times 33000}$$

where P represents the mean effective pressure in pounds per square inch; L the length of the stroke in feet; A the area in square inches of the piston less the area of the piston rod or tail rod, if any; and N the number of revolutions per minute. The total indicated horsepower of a double-acting cylinder is the sum of the horsepower developed in the two ends, and the indicated horsepower of a multi-cylinder engine is the sum of the horsepower developed in each cylinder.

For two-cycle engines the indicated horsepower for each single-acting working cylinder, and for each end of each double-acting working cylinder, shall be found by using the formula—

$$\text{I.hp.} = \frac{PLAN}{33000}$$

where the symbols have the same meaning as above. The total indicated horsepower of all working cylinders is the sum of the horsepower developed in each cylinder, and in each double-acting cylinder it is the sum of the horsepower developed in each end.

The mean effective pressure, P, should be found by dividing the area of the diagram in square inches, as determined with a correct planimeter, by the length of the diagram, in inches, and multiplying the quotient by the average corrected scale of the indicator spring.

Accuracy tests must be applied to determine the acceptability of the mean effective pressure thus determined, especially when cylinder pressures and spring scales are high (as for injection oil engines) and card areas small, as is more usual for two-cycle engines of smaller size.

40 *Brake Horsepower.* The brake horsepower is found by multiplying the net force, W in pounds on the brake arm, by the circumference of the circle whose radius is the horizontal distance, L, in feet between the center of the shaft and the bearing point or weight center at the end of the brake arm, and by N, the number of revolutions of the brake shaft per minute, and dividing the final product by 33,000.

$$\text{B.hp.} = \frac{2\pi LWN}{33000}$$

Reference must be made to the Code on Instruments and Apparatus for descriptions of brakes, especially the hydraulic and electric dynamometer types, referred to in Par. 17 for methods of applying them, and especially for methods of correctly determining the net force W from the gross force, and for incidental or special errors in brake use and calculations.

41 *Electrical Horsepower.* The electrical horsepower of a generator is found by dividing the output at the terminals expressed in kilowatts by the constant 0.7457. In the case of an alternating-current generator, the quantity of output determined whether expressed in electrical horsepower or kilowatts, should be the net output. When the power for excitation or ventilation is taken directly from the engine shaft, the net output is that indicated at the terminals. When the exciting current is obtained from the generator through a motor or from some outside source, the net output is found by deducting the current furnished as excitation from that delivered at the terminals. When the exciter is driven from the engine shaft, the engine supplies the belt losses and the exciter losses without being credited. When the exciting current is obtained from the generator through a motor, and the excitation current is deducted from that delivered at the terminals, the exciter losses are not credited. Where as with a separately driven exciter, it is really the exciter net output which is deducted from the power delivered at the terminals. In a close test these differences may be of some interest. It is regarded as important to have the basis of power determination definitely agreed to in advance to suit the particular case and to be suitable to local conditions prevailing.

42 *Thermal Efficiency.* The fraction of the heat consumption converted into work is the "thermal efficiency" and is found by dividing 2547 (B.t.u. equivalent to 1 hp-hr.) by the number of heat units actually supplied per indicated hp-hr., Par. 37. The quotient is multiplied by 100 to express the thermal efficiency in per cent. The formula is

$$\text{Thermal Efficiency} = \frac{2547}{HQ}$$

where H = heating value of the fuel (high value), B.t.u. per pound or per cubic foot and Q = amount of fuel supplied per indicated horsepower hour, pounds or cubic feet.

Data and Results

43 The data and results should be reported in accordance with the form of Table 1 for horsepower tests made at constant speed, and in accordance with the form of Table 2 and chart, Fig. 1, for horsepower tests made over the whole speed range of a variable-speed engine. Lines may be omitted if not required for the object of the test, or new lines may be added for additional data desired. For marine engines either or both forms may be used.

TABLE 1 DATA AND RESULTS OF INTERNAL-COMBUSTION ENGINE TEST AT CONSTANT SPEED

General Information

(1) Date of test..
(2) Location..
(3) Owner..
(4) Builder..
(5) Test conducted by..
(6) Object of test..

Description, Dimensions, etc.

(7) Type of engine, two- or four-cycle, single- or double-acting, horizontal or vertical, if four cycle, the valve arrangement L, T, or I head, if two-cycle, the type of scavenging, if single-acting, whether crosshead or trunk piston, if multi-cylinder the arrangement of cylinders and cranks, gas or liquid fuel, and if liquid fuel, carburetor type, or other class name fixing manner of treating fuel, such as Hvid, Diesel, or solid injection for example..
(8) Class of service, stationary and special feature, marine, aircraft or vehicle, and what kind..
(9) Auxiliaries attached, such as magneto, fuel-injection pump, fuel-circulating pump, lubricating-oil pumps, jacket circulating pumps, scavenging pumps, spray-air compressor, maneuvering or starting air compressor, radiator fans, oil or fuel coolers or heaters..............
(10) Auxiliaries, independent or separately driven, and power..........
(11) Details of type, capacity, maker's name and other features of auxiliaries..
(12) Rated brake horsepower of engine, or kw. of electric generating set, and speed..
(13) Grade of fuel for which engine is designed, kind of gas or specification of liquid fuel, and what was used in test..................
(14) Special structural features for fuel utilization..................
(15) Special structural features of speed and power control, and governor or reversing gear..
Number of working cylinders..
(16) Diameter of all cylinders working, 4-cycle or 2-cycle..........in.
(17) Diameter of piston and tail rods of working cylinders.........in.
(18) Stroke of working cylinders..............................ft.
(19) Head-end hp. constant for working cylinders, (stroke × net piston area ÷ 33,000)..
(20) Crank-end hp. constant for working cylinders, (stroke × net piston area ÷ 33,000)..
(21) Capacity of generator or other apparatus consuming power of engine..
(22) Characteristics of generator,—d.c. or a.c., volts, cycles, phase....

Test Data and Results

(23) Duration of test.......................................hr.

Pressures, Average

(24) Barometric pressure......in. of mercury......lb. per sq. in.
(25) Spray-air pressure (air injection Diesel engines) average (say whether gage or absolute)..........................lb. per sq. in.
(26) Exhaust back pressure..............................in. of water
(27) Jacket water supply pressure..........................lb. per sq. in.
(28) Manifold vacuum (carburetor engines).............in. of water
(29) Gas pressure in main gaseous fuel....inches water..lb. per sq. in.
(30) Lubricating-oil pressure, circulating forced-feed system...... ....lb. per sq. in.
(31) Scavenging-air pressure average, two-cycle engines..lb. per sq. in.

Temperatures

(32) Engine-room temperature..........................deg. fahr.
(33) Temperature of fuel..................................deg. fahr.
(34) Temperature of main air supply....................deg. fahr
Location of thermometer..
(35) Temperature of main jacket water or oil inlet..........deg. fahr.
(36) Temperature of main jacket water or oil outlet........deg. fahr.
(37) Temperature at inlet of separate jacket ....deg. fahr.
(38) Temperature at outlet of separate jacket ....deg. fahr.
(39) Temperature of mixture at intake port (carburetor engine) ....deg. fahr.

Fuel Properties

(40) Heating value of gas, high value..............B.t.u. per cu. ft.
(41) Heating value of liquid fuel, high value............B.t.u. per lb.

Total Quantities

(42) Total gaseous fuel at meter pressure & temperature cu. ft
(43) Correction factor for gas (Item 29 × Item 33 + 460 ÷ Item 29 × Item 39 + 460)..
(44) Total gaseous fuel at carburetor or atmospheric pressure....cu. ft.
(45) Total liquid fuel..lb.

Hourly Quantities

(46) Total gaseous fuel per hour at calorimeter or atmospheric pressure and temperature...cu. ft.
(47) Total liquid fuel per hour..................................lb.

Heat Consumption

(48) Total heat in fuel supplied per hour (Item 46 × Item 40, or Item 47 × Item 41)..B.t.u.

Indicator Diagrams

(49) Mean effective pressure, average, four-cycle.........lb. per sq. in.
(50) Mean effective pressure working cylinders, average, two-cycle ....lb. per sq. in.

Speed

(51) Revolutions per minute.................................r.p.m.
(52) Piston speed ....ft. per min.

Power

(53) Indicated horsepower of all working cylinders..............i.hp.
(54) Indicated horsepower of each single acting cylinder, or each end of each double acting four cycle
No. 1 head end..i.hp.
No. 1 crank end ....i.hp.
No. 2 head end..i.hp.
No. 3 crank end...i.hp.
etc.

(55) Brake horsepower developed by whole engine by brake or dynamometer measurement . . . . b.hp.
(a) Brake mean effective pressure . . . . lb. per sq. in.
(56) Total horsepower of independent scavenging pump and injection air compressor . . . . hp.
(57) Net or actual brake horsepower of engine, (Item 55 − Item 56) . . . . b.hp.
(a) Net brake mean effective pressure . . . . lb. per sq. in.
(b) Net torque at 1 ft. radius equivalent to brake horsepower . . . . ft-lb.
(58) Friction and attached auxiliaries horsepower (Item 53–Item 55) . . . . hp.

Economy Results
Fuel consumption per i.hp-hr., gas (Item 46 ÷ Item 53) . . cu. ft.
Fuel consumption per i.hp-hr., liquid (Item 47 ÷ Item 53) . . . . lb.
(59) Fuel consumption per b.hp-hr.: Gas (Item 46 ÷ Item 57) . . . . cu. ft.
Liquid (Item 47 ÷ Item 57) . . . . lb.
(60) Heat consumed per i.hp-hr.: (Item 48 ÷ Item 53) . . . . B.t.u.
(61) Heat consumed per b.hp-hr. (Item 48 ÷ Item 57) . . . . B.t.u.

Efficiency Results
(62) Thermal efficiency referred to i.hp. (2547 ÷ Item 60) . . per cent
(63) Thermal efficiency referred to b.hp. (2547 ÷ Item 61) . . per cent

Specimen Diagrams
(64) Sample diagram each working cylinder . . . .

Electrical Data
(65) Average volts each phase . . . . volts
(66) Average amperes each phase . . . . amp.
(67) Total electrical output corrected for winding 1, 2 or 3 phase. kva.
(68) Power factor . . . . per cent
(69) Total output in kilowatts . . . . kw.
(70) Field power . . . . kw.
(71) Net output in kilowatts . . . . kw.
(a) Field volts . . . .
(b) Field amperes . . . .

Power and Economy
(72) Electrical horsepower developed (Item 70 ÷ 0.7457) . . . .
(73) Fuel consumed per net kw-hr. Gaseous (Item 46 ÷ Item 70) . cu. ft.
Liquid (Item 53 ÷ Item 83) . . . . lb.
(74) Heat consumed per net kw-hr. (Item 48 ÷ Item 70) . . . . B.t.u.

TABLE 2 DATA AND RESULTS OF INTERNAL-COMBUSTION ENGINE TEST AT VARIABLE TORQUE AND SPEED

General Information

(1) Date of test . . . .
(2) Location . . . .
(3) Owner . . . .
(4) Builder . . . .
(5) Test conducted by . . . .
(6) Object of test . . . .

Description, Dimensions, etc.

(7) Type of engine, carburetor or oil, single- or double-acting, if four-cycle, the valve arrangement L, T, or I head, if two-cycle the type of scavenging, if single-acting, whether crosshead or trunk piston, if multi-cylinder, the cylinder and crank arrangement and if radial cylinders whether cylinders are fixed or rotate, and, means of fuel utilization by class name, such as Hvid, Diesel, or solid injection for example . . . .
(8) Class of service, aircraft, automobile, truck tractor, railroad or marine, for gear, electric or direct propeller drive, single direction or reversing . . . .
(9) Auxiliaries, attached and independent, kind, maker's name, capacity, etc . . . .
(10) Rated horsepower and speed, if any, or speed at maximum torque
(11) Bore and stroke of all working cylinders . . . .
(12) Weight of engine complete . . . .

		Run Number 1	2	3
(13) Brake horsepower	b.hp.	. . . .	. . . .	. . . .
(14) Speed	r.p.m.	. . . .	. . . .	. . . .
(15) Total fuel	lb.	. . . .	. . . .	. . . .
(16) Time of run	hr.	. . . .	. . . .	. . . .
(17) Fuel per hour	lb.	. . . .	. . . .	. . . .
(18) Fuel per hour per b.hp.	lb.	. . . .	. . . .	. . . .
(19) Heating value of fuel . . . B.t.u.	lb.	. . . .	. . . .	. . . .
(20) Heat consumed per hour (Item 17 × Item 19)	B.t.u.	. . . .	. . . .	. . . .
(21) Heat consumed per hour, per b.hp. (Item 20 ÷ Item 13)	B.t.u.	. . . .	. . . .	. . . .
(22) Thermal efficiency (2547 ÷ Item 21)	per cent	. . . .	. . . .	. . . .
(23) Mean effective pressure equivalent to brake horsepower	lb. sq. in.	. . . .	. . . .	. . . .
(24) Torque at one foot radius equivalent to brake horsepower	ft-lb.	. . . .	. . . .	. . . .
(25) Fig. 1 Curve of r.p.m. plotted horizontal against vertical		. . . .	. . . .	. . . .
(a) Brake horsepower, Item 13		. . . .	. . . .	. . . .
(b) Fuel per hour (Item 17)		. . . .	. . . .	. . . .
(c) Fuel per hour per b.hp. (Item 18)		. . . .	. . . .	. . . .
(d) Thermal efficiency (Item 22)		. . . .	. . . .	. . . .
(e) Brake mean effective pressure (Item 23)		. . . .	. . . .	. . . .
(f) Torque (Item 24)		. . . .	. . . .	. . . .

Economic Features of the Machine-Tool Industry

(Continued from page 153)

times. That reserve is cost, not profit. If he does not have such a reserve he goes out of business by the bankruptcy route. An investigation showed that although they made a large part of the output, representative machine-tool companies did not earn quite 9 per cent on their investment for 10 years preceding the war. All of those earnings could not be taken out in cash dividends. Most of the earnings were reserves to carry over depressions.

Before the war, machine-tool prices were very low compared to the utility they gave their buyers. The prices advanced with the war, but advanced far less than prices of most war goods. The industry made money of course, but out of larger production, not out of excessive prices. The tax laws penalized the industry unjustly. The machine-tool builders financed their own expansion instead of asking the Government to do it. They now find themselves with expanded capacity that is much too large for any demand likely to arise in a few years. The prewar demand was largely foreign, and that is gone. Likewise the rapid growth of the automobile industry required many machine tools that have now been supplied. The second-hand market was glutted with all sorts of tools from dismantled war shops. All these factors combined to make the machine-tool business a very unhappy one for nearly three years.

As to remedies, the machine-tool builders have few choices. The first is, to design something new and revolutionary that will make a new market by obsolescence of old types. Naturally, this is not easy, and very few companies will be able to work out this plan.

The second is, by mergers and consolidations to reconcentrate the industry in fewer shops and reduce overhead in proportion. But the individualistic machine-tool builder prefers to be his own boss, and may do his best work as such.

The third choice is to take on some entirely different product along with machine tools, which involves establishing an entirely separate selling plan, connections, etc.—not an easy thing to do.

The fourth choice, for those who cannot for any reason take either of the other three, is to quit the field before bankruptcy closes the shop doors.

The machine-tool industry has an ethical standard—that simple one on which dependeth all the law and the profits, the Golden Rule. Through long years the leading machine-tool builders have built up their business on that standard. The violation of the Golden Rule by some of their customers cost them a lot of money in the deflation of the last boom.

Abuses became so audacious and common that the industry is now determined that the Golden Rule is good enough to work both ways. To protect the industry and its honorable, considerate customers, steps are being taken to make available to the industry full information regarding those who use unfair methods of various sorts. The responsible, reliable machine-tool builder will hereafter take an order to be a contract, not a buyer's option subject to cancellation. He believes in a price that is right all round, right for the customer, right for his own stockholders, for his employees, for his family, and for himself. He believes in the same price for all his customers, without the discriminatory shading here and there that only gives some shrewd buyers an inside edge on the fair ones who are willing to pay a right price.

As a result of the depression of 1921 and 1922 the wide-awake machine-tool builder is giving close attention to the economics of his industry and the nature of his demand. He is studying what to do and what not to do at various stages of his business cycle. He is contributing statistics whereby the stages of his cycle are disclosed. In his mind he is correlating his shop as a part of the industry, and his industry as a part of the big industrial machine that turns out goods of all kinds for the world's comfort. He realizes that his is one of the intermittent gears in the machine, and that as long as the other elements of the machine compel him to work so much more slowly at times, he must regulate his finances so as not to get caught in a squeeze. Such correlation will make a better industry with sounder, saner conditions than the machine-tool builder has ever known, either in booms or depressions.

ENGINEERING RESEARCH

A Department Conducted by the Research Committee of the A.S.M.E.

Résumé of the Month

A—Research Results

The purpose of this section of Engineering Research is to give the origin of research information which has been completed, to give a résumé of research results with formulas or curves where such may be readily given, and to report results of non-extensive researches which in the opinion of the investigators do not warrant a paper.

Electrochemistry A1-23. A New Method for Determining the Rate of Sulphation of Storage-Battery Plates. Technologic Paper No. 225 of the Bureau of Standards, just issued, describes experiments which have been made to develop a speedy and accurate method for measuring the effect of impurities in storage-battery electrolyte. In the present paper the fundamental theory of the method and measurements of the rate of sulphation of the plates in the pure acid are given. An extension of the investigation is planned which will include the effect of added impurities following the method here described. Address Superintendent of Documents, Government Printing Office, Washington, D. C. Price 5 cents.

Fluid Flow A1-23. Experiments in the Flow of Water in Vertical Tubes of Diverging Cross-Section. Messrs. R. H. Morris and A. J. Houston have recently completed a series of experiments on this subject at the Hydraulic Laboratory of the Massachusetts Institute of Technology. This research was a continuation of the one carried on a year or so previous under the direction of Prof. George E. Russell.

It was hoped to establish some relation between the length and angle of the tube, or the length and ratio of end areas, which would give the maximum discharge for a given head. The authors in their conclusions state that, while the data obtained are unsufficient to warrant the deduction of any general formula expressing the relation between angle and length of tube which would give the greatest discharge for a given head, it may be quite definitely said that, within the limits of the present investigation, for any given head, the longer the tube the greater the discharge and, for a given length of tube, the maximum discharge is obtained with a tube having an angle of between seven and ten degrees. They feel that there is a great field for further investigation along these lines.

One copy of this research is on file with the Librarian of the Engineering Societies Library, 29 West 39th Street, New York.

Fuel Utilization A1-23. Carbon Monoxide in the Products of Combustion from Natural-Gas Burners. Many gas appliances are notoriously inefficient. Solid-top stoves with low-set burners and grid-top stoves with low-set burners consume from two to eight times as much gas as stoves with raised burners and grid tops. On account of the liberation of carbon monoxide, a poisonous gas, with the products of combustion when the flame is improperly aerated, it is not practical to place burners at the distance from utensils where the maximum efficiency is obtained. Burners of the "star" type should be placed about one in., the "slot" burner about $^3/_4$ in., and the "disk" type about $1^1/_4$ in. from the utensil.

From the many tests for carbon monoxide made with five different burners and different types of flames at rates of consumption of 6.0 and 8.0 cu. ft. per hour (6480 and 8640 B.t.u. per hour), the maximum rate of liberation of carbon monoxide was found to be 0.25 cu. ft. per hour and was obtained with a very soft flame and a close position of utensil which caused the flame to "float" and extend up the side of utensil. It is not a dangerous rate unless one works directly over the bürner, or several burners are in use at the same time for several hours, or the room is unventilated.

No carbon monoxide was found where the blue inner cone of the flame was not allowed to touch the utensil. A yellow flame will produce carbon monoxide at a rate much greater than a blue flame when the utensil is so close to the burner as to cause a floating flame.

A natural-gas flame was found to be smothered from deficiency of oxygen when the content of the atmosphere had been diminished to about 15.5 per cent. When one considers the natural ventilation which takes place through the windows and doors it would seem that the danger from carbon monoxide poisoning with natural-gas top burners is quite remote.

This Technologic Paper No. 212 of the Bureau of Standards was prepared by Messrs. I. V. Brumbaugh and G. W. Jones and may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C., for 10 cents.

Fuel Utilization A2-23. Value of Coke, Anthracite, and Bituminous Coal for Generating Steam in a Low-Pressure Cast-Iron Boiler. Technical Paper No. 303 of the Bureau of Mines records the results of a series of tests conducted primarily for the purpose of determining the relative steaming values of coke, anthracite, and bituminous coal when burned in a low-pressure boiler, and fired by hand in fairly large quantities at a time.

A secondary purpose of the tests was to separate the heat losses, and to examine them carefully to determine the change in efficiency with the method of firing the fuel and manipulation of the draft dampers, with the rate of evaporation, and with the various fuels burned.

Address Superintendent of Documents, Government Printing Office, Washington, D. C., for a copy of this paper. Price per copy, 10 cents.

Fuel Utilization A3-23. Economic Combustion of Waste Fuels. Since its establishment the Bureau of Mines has conducted investigations relating to efficiency in the utilization of fuels, including the utilization of fuels of such low grade that they are in many places classed as waste. Because of the decreasing supply and increasing cost of high-grade fuels, the efficient utilization of those that are low-grade is becoming a problem of major importance to many industries and to the commercial progress of the nation. The data in this paper, consequently, are published as a contribution to the literature on the conservation of national resources.

This bulletin known as Technical Paper No. 279 was prepared by Mr. David Moffat Myers. It consists of 51 pages and may be obtained for 10 cents from the Superintendent of Documents, Government Printing Office, Washington, D. C.

Fuels A1-23. Economic Combustion of Waste Fuels. See *Fuel Utilization A3-23.*

Gases A1-23. Carbon Monoxide in the Products of Combustion from Natural-Gas Burners. See *Fuel Utilization A1-23*

Gases A2-23. Fixation and Utilization of Nitrogen. This report has been prepared in order to correlate and make available under one cover such information on the fixation and utilization of nitrogen, collected by the Nitrate Division since its organization in July, 1917, as may aid in the further development of that art in the United States. It was prepared with the assistance of the Fixed Nitrogen Research Laboratory of the Department of Agriculture and is based to a very considerable extent on reports, papers and articles prepared by the officers and civilians associated from time to time with the activities of the Nitrate Division, as well as on the published technical and economic papers of several others. A bibliography of many of the papers pertaining thereto that have appeared in the last few years is included. Address Nitrate Division, Ordnance Office, War Department, Washington, D. C.

Lubricants A1-23 Reclamation of Used Petroleum Lubricating Oils. A series of tests recently completed by the Bureau of Standards' staff have demonstrated that used lubricating oils may be reclaimed by apparatus already commercially available and thus saved for further use. Such reclaimed oils will pass all the commonly accepted tests for new oils, such as flash point, viscosity, and sediment. This investigation is fully described in Technologic Paper No. 223 of the Bureau of Standards, for sale by the Superintendent of Documents, Government Printing Office, Washington, D. C. at 5 cents per copy.

Petroleum and Allied Substances A1-23. Reclamation of Used Petroleum Lubricating Oils. See *Lubricants A1-23.*

Radioactivity A1-23. Mesothorium. The chemistry of mesothorium, the radioactive element found in monazite sand and other thorium minerals, which is used as a substitute for radium in the manufacture of certain luminous paints and for medicinal purposes, is discussed in Technical Paper 265, just issued by the United States Bureau of Mines.

B—Research in Progress

The purpose of this section of Engineering Research is to bring together those who are working on the same problem for coöperation or conference, to prevent unnecessary duplication of work, and to inform the profession of the investigators who are engaged upon research problems. The addresses of these investigators are given for the purpose of correspondence.

Building Materials B1-23. Fire Resistance of Hollow Building Tile. An investigation of the fire resistance and related physical properties of hollow building tile has been conducted by the Bureau of Standards during the past two years in coöperation with the Hollow Building Tile Association. A furnace, suitable for making fire tests of small panels up to 4 ft. square, was built and tests of unprotected panels built from tile of representative clays have been made in order to establish characteristic behavior under fire. A wide range in fire resistance was found, depending mainly on the mineral composition of the clays employed. As a possible means of increasing fire-resisting properties, grog additions up to 10 per cent were tried, but it was found that the small addition which can be conveniently made in manufacturing practice had no effect, and that additions of 5 per cent or more decreased the fire resistance. The protection afforded by typical plasters has been determined, obtaining, generally excellent results.

The effect of the addition of combustible filler to the raw material, of the fineness of grinding of the raw material, of the size of the unit, and of changes in design of the tile, will be ascertained. Address the Director of Bureau of Standards, Washington, D. C.

Fire Prevention B1-23. Fire Resistance of Hollow Building Tile. See *Building Materials B1-23.*

Electrical Instruments B1-23. Electric Telemeter. During the past two years or more the Bureau of Standards has been engaged in developing electric telemetric devices based upon the fact that carbon contact resistances vary with pressures or displacements applied to their terminals. In the past there have been several inherent difficulties with apparatus of this kind. The Bureau has investigated all of these sources of trouble and has found means of eliminating all of them to a degree which makes the apparatus well adapted to a great variety of engineering measurements.

These measurements include those of strains in bridge members and other engineering structures, of accelerations, vibrations, and pressures of practically every description. The apparatus can be made either indicating or recording as desired. Up to the present time both indicating and recording instruments embodying this principle have been made for and largely used by the Bureau of Aeronautics of the Navy Department for measuring stresses both in airplane members and dirigibles where it is very important to read such stresses at a point more or less remote from the member under test. Similar apparatus has also been used extensively by the Bureau of Standards in laboratory tests on large structural members and also in connection with certain dynamometer work, and for much of this work the new instruments have been found to be substantially equal in accuracy to anything heretofore available in the line of indicating instruments, and they possess the additional advantage of permitting remote reading as well as graphic records to be made when desirable. Work is now in progress on the extension of the field of application of these instruments to various lines of engineering work to which they are adapted.

Instruments and Apparatus B1-23. Electric Telemeter. See *Electrical Instruments B1-23.*

F—Bibliographies

The purpose of this section of Engineering Research is to inform the profession of bibliographies which have been prepared. In general this work is done at the expense of the Society. Extensive bibliographies require the approval of the Research Committee. All bibliographies are loaned for a period of one month only. Additional copies are available, however, for periods of two weeks to members of the A.S.M.E These bibliographies are on file at the headquarters of the Society.

Electricity, General F1-23. Electrical Insulating Material. In connection with the Bureau's investigation of the properties of certain types of electrical insulating materials, a rather comprehensive bibliography of papers, books, patents, and periodicals has been prepared.

Since a considerable demand has arisen for copies of these, they have been issued in mimeographed form as Letter Circulars Nos. 50 and 51 "Bibliography of books and titles of periodicals on properties and uses of insulating materials" and "Lists of the more important U. S. patents covering the materials and methods of manufacture of an insulating material." Only a limited supply of these two letter circulars is available, but a copy will be sent on request, as long as the supply lasts, to any person who can show an actual need for them. Address the Director, Bureau of Standards, Washington, D. C.

Gases F2-23. Fixation and Utilization of Nitrogen. An eleven-page bibliography on this subject forms an appendix to Report No. 2041 of the Nitrate Division of the War Department just issued. It contains references to material published from 1917 to the present.

CORRESPONDENCE

Contributions to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities and policies of the Society in Research and Standardization.

The Surge-Tank Problem

In discussing a paper on surge tanks by Professor Durand[1] which appeared in the October, 1921, issue of Mechanical Engineering (p. 643), R. D. Johnson,[2] in a letter published in a later issue (August, 1922, p. 541) stated that a differential surge tank *without exception* is cheaper than a simple surge tank for fulfilling the same conditions. This statement was challenged by B. F. Jakobsen[3] in a communication printed in Mechanical Engineering, November, 1922, p. 764, and further in the closure to the discussion of his paper on surge tanks before the American Society of Civil Engineers. The paper in question is mainly devoted to a general consideration of the problem of surge-tank action in the Kerckhoff plant of the San Joaquin Light and Power Corporation. Special reference is made to the design and tests of the Kerckhoff surge tank, a simple cone-shaped tank 17 ft. in diameter at the top and 39.5 ft. at the bottom.

In his closure Mr. Jakobsen states that the Larner-Johnson Valve and Engineering Co. was asked to furnish a design of a differential surge tank and accordingly submitted one consisting of two independent shafts, one 7 ft. in diameter rising directly above the tunnel, and the other 20 ft. in diameter offset from the tunnel and connected at the bottom to the tunnel and at the top to the riser. This design was not adopted because it would have been as expensive to excavate as the simple surge tank, and also for the following reasons:

"This differential surge tank would permit an increase from no load to full load in 3 min., as will also the Kerckhoff surge tank. For such a load increase, this tank is comparable with the Kerckhoff tank. However, when the load is increased instantaneously, or within a few seconds, from 1000 to 1500 sec-ft. (1500 sec-ft. being about full load on the plant), the water surface in the differential surge tank is decreased from Elevation 965 to Elevation 932, or the head on the plant is reduced by 33 ft. (about 10 per cent of the total head) in 10 sec.; whereas in the Kerckhoff surge tank the decrease in head is only 8 ft. in 10 sec. Both surge tanks meet the condition imposed on them, but during the first minute after the turbine gates have opened, the plant with the Kerchkoff surge tank supplies on an average nearly 2000 kw. more than the one with the differential surge tank, and 10 sec. after the moment of regulation the Kerckhoff surge tank supplies about 2700 kw. more than the differential surge tank. As this is nearly the ultimate capacity of the plant and for nearly full gate and at a time when every kilowatt counts, it is an advantage in favor of the Kerckhoff surge tank. The normal full load on the Kerckhoff plant is 35,000 kw., although 40,000 kw. have been generated for several hours when the tail-race elevation was relatively low."

Denying the statement of R. D. Johnson that the differential principle produces without exception a cheaper tank, Mr. Jakobsen believes that "the differential surge tank has its advantages, but it is not always the best possible type, as is shown by the previous discussion. Each plant requires a special study, and the size and shape of the tank depend on the conditions to be met and the physical constants of the plant. The success of the design depends also largely on the designer's ability to appreciate properly the operating conditions which will be imposed on the plant."

The dispute between Mr. Jakobsen and the advocates of the differential surge-tank principle resolves itself, therefore, not to the question as to whether the differential surge tank has its advantages over the simple type under conditions favorable to the former, but whether there can be any conditions under which the simple tank might be preferred, and, in particular, whether the conditions at the Kerckhoff project were such as to warrant the use of the differential surge tank in preference to the simple surge tank.

The editors have recived a number of letters advocating the differential-tank principle, but because of lack of space it is impossible to reproduce all of them, notwithstanding their interest. It has

[1] Prof. M. E., Leland Stanford Jr. Univ., Past Vice-Pres. Am.Soc.M.E.
[2] Hydraulic Engr., New York, N. Y. Mem. Am Soc M.E.
[3] Construction, Hydraulic and Electrical Engr, Fresno, Cal

been decided, therefore, to publish in full a communication received from Mr. Johnson, the earliest champion of the cause of the differential surge tank, and to give extracts from the other letters. It is believed that this will serve to bring out the salient points of the discussion.

R. D. Johnson's Letter of November 29

To the Editor:

With further reference to my letter on the subject of Surge Tanks, appearing in your December number, I now have in hand a reprint of Mr. Jackobsen's closure of his A.S.C.E. paper to which he referred in your November issue and therefore I can answer his statements with a little more idea of what he is driving at.

He shows two surge diagrams, one for a small differential surge tank and one for a larger conical simple tank, which have the same amplitude of surge for a given instantaneous load change.

The load on the plant previous to the instantaneous load demand is the same in both cases and is proportional to the product of 1000 c.f.s. and a head represented by elevation 961 at the tank. The load change, he says, is such as to practically reach the limit of the capacity of the turbines, when discharging 1500 c.f.s. at the lessened head (equal in the two cases) which exists at the lowest point of the surge shown as Elevation 932. These two cases are therefore equivalent, if the computations are correct, and serve in no way to prove his contention of a "distinct disadvantage." There is obviously no shortage of power of 2000 or 2700 kw. or any other amount and it was some time before I could guess where he got this idea, but it appears that he has figured a hypothetical shortage proportional to the difference of head, in the two cases, at precisely the same time abscissas, which, of course, has no practical bearing on the case

It seems superfluous to point out that power output is made up of two factors, one of which is the head on which Mr. Jakobsen bases his conclusions and the other, which he does not take into account, is the varying discharge of the turbines during a surge due to the action of the governor in its effort to maintain at constant value the additional load which has been assumed to be suddenly demanded in the beginning.

The governor is capable of moving at a far greater rate of speed than is required to follow up the drop of water level either in a simple tank or in a differential regulator of proper design with adequate area of riser. The sudden accession of load is therefore adhered to in either case, if the governor is any good.

If he has inadvertently assumed a constant discharge of the turbines during the surge, thus making it possible to claim a shortage in power output proportional to a difference in head (at the same time abscissas in the two cases), he is then subverting the facts in substantiation of a claim which has no bearing on the practical operation of a power plant.

Some light on his method of figuring surges may be gleaned from a glance at his Fig. 9. This purports to be a surge diagram following a gradual increase in load from 9,000 to 27,850 kw. in 70 sec., after which, during the remaining minutes shown in the figure, the load is supposed to be maintained constant. At least, he gives the same figure for it when the water quiets down at Elevation 970.2.

While this is quite possible with a varying discharge through the turbines, it stretches the imagination to understand how the load can remain constant with a constant discharge of 1145 c.f.s. while, at the same time, the head is varying from elevation 954.1 to elevation 982.3, which variation, with a constant discharge of the turbines, would amount to as much as 3000 hp. to say nothing about the magic invoked to keep the discharge constant. An explanation of this is desirable.

This little study may furnish an index to his process of thought and may account for his views in regard to a shortage of power, due to differential action.

The two equivalent tanks which he illustrates differ in volume and they could only be considered to cost the same, as he says they do, by using a larger unit price on the extra shaft for the riser; but it is well known that the riser may just as well be placed within the tank, by adding its volume to the single excavation, or it might be run up on the outside slope of the hill, if the topography is suitable for such a course.

This particular sketch, I find upon inquiry, is a study which passed out of the office of the Larner-Johnson Valve and Engineering Company in the course of correspondence, setting forth arguments in favor of the differential regulator, and it never had any such final consideration as is always given to a design, favorably received, where there seems to be a desire to go thoroughly into the matter, looking toward its adoption.

Fortunately, it seems to be about all right, on casual inspection, except that neither this regulator with its small riser nor his own surge tank would be considered adequate for the usual requirements with which we are familiar, especially for low or medium-high heads.

Frequently such plants are fed by wood-stave pipe lines regulated by steel tanks built on high towers, where spilling large rates of flow at a high elevation is economically out of the question and where every foot of surge both upward and downward is a matter of importance. These are the very cases for which Mr. Jakobsen promised, at least by implication, to set forth in his advertised article, something better than the differential regulator and many will be disappointed to find nothing in support of his assertions.

The surge in the Kerckhoff tank, shown in Fig. 16 (Waldman's discussion of Jakobsen's paper), does not take into account the augmenting effect of governor action, and inasmuch as this is the only thing which works against the friction of the conduit to increase and keep alive fluctuations in water level, it will probably be clear to those familiar with these questions that the surges as shown would be much amplified if the customary governing action was to be imposed upon them.

Even here it will be seen that the water level returns, upon the first recoil, to an elevation slightly greater than that at which it started, although no load has meantime been rejected. This condition would of course be worse with a governor trying to hold the power output at constant value.

When a power plant is supposed, at times, to stand upon its own feet in respect to regulation and not therefore always able to shift some of its responsibility to other plants in parallel, which may be better equipped for the purpose, it is not considered good practice to permit much instability in the water level.

In Mr. Jakobsen's closing words, he distinctly leaves it to be inferred that rapid damping of oscillations is due to the conical shape of a surge tank.

With the use of a simple tank of whatever shape there is only one thing that tends rapidly to kill surges, and that is excessive friction in the conduit.

In the case cited, very rapid damping of oscillations would be taken as an indication that an unwarranted amount of useful head was being wasted in the conduit.

With a simple tank, rapid damping, so essential, if often very expensive; it is not a function of the conical shape and, furthermore, Mr. Jakobsen's example does not indicate rapid damping.

With differential action, however, the rate of damping is increased without the loss of useful head on the turbines.

In closing, I wish again to refer to the words of mine, which Mr. Jakobsen quoted at the beginning of his letter, viz: "It is difficult for the writer to find any excuse for omitting the differential principle when its use, without exception, produces a cheaper surge tank, which will fulfill the same conditions."

It must be understood that this is merely a rule and possibly subject to the inaccuracy of all rules which are said to require an exception to prove them. However, in running through my mind some two score surge-tank designs with which I am familiar, I am able to state that the ratio of cost of the simple tank to the differential varies greatly with the physical conditions; it has rarely been found higher than 3, not infrequently as high as 2, commonly as high as 1.75, sometimes lower, but never, up to date, nearly as low as unity.

The ratios seem to be larger for structural tanks than for excavated ones and it is probably in that field, if anywhere, that an exception might be found.

Perhaps someone will feel enough interest in the matter to ferret out and publish the exception which is now lacking for a thorough establishment of the rule and then its acceptance might possibly be made universal.

New York, N. Y. R. D. Johnson.

In a letter dated November 27, Norman R. Gibson[4] questions whether Mr. Jakobsen's conclusions were based upon a comparison of the actual performance of representative surge tanks of both types and adds that it is obvious that not all surge-tank designs are correct, nor any one design of any type suitable for all conditions.

T. H. Hogg[5] in a letter dated November 21 points out that "the differential tank acceleration is faster than that of the simple tank, due to the greater drop in the water surface in the riser of the differential tank during the early part of the first quarter cycle, which results in a lower operating head on the turbine. If sufficient flywheel is provided to prevent an undue change of speed during the initial movement of the governor this condition does not give less power during the period than would result from the action of a simple tank, because the greater acceleration in the conduit, together with the capacity of the riser itself, more than compensates for the additional decrease in head, and as a result more power is available during this period with the differential tank than with the simple tank. Since the water level in the simple tank at the end of the first quarter-cycle is lower than in the differential tank, a greater amount of water is required by the turbine to meet the power demand, and, therefore, the gate opening on the turbine and hence the work done by the governor must be greater than for a differential tank.

"While the drop in the water level in the riser of the differential tank is more rapid than in the simple tank, it requires considerably greater time to reach its low level than the time necessary for the governor to make a full-gate stroke, and it is quite evident that with a governor set to take care of a given load change in a reasonable time, with constant head, it is perfectly capable of taking care of the same change with the slight and comparatively gradual change which occurs in the riser during the interval."

F. J. Howes[6] (letter dated November 13) states that "a thorough discussion of the relative merits of simple and differential surge tanks is made so difficult by the vast amount of arithmetical integration required that a proper sense of proportion is likely to be lost. The writer had occasion not long ago to compare the dimensions of both types of tank which would be required to give equivalent speed regulation on a station of 33,000-kw. capacity on a head of 130 ft. The results from a differential tank 52 ft. in diameter had as good commercial characteristics as could have been obtained from a simple tank 90 ft. in diameter, in spite of the extreme drop in head occurring on the occasion of a sudden demand."

Eugene E. Halmos[7] (letter dated November 16) says that from his experience the differential surge tank results in considerable economy in first cost where a fixed maximum or minimum head on the conduit or penstocks is of importance. He adds, however, that it is just conceivable that where the surge tank is an unlined excavated hole in solid rock, the cost of additional excavation to obtain the diameter necessary for an equivalent simple tank might balance the cost of the riser of the differential tank.

Lewis F. Moody[8] in his letter of December 2, 1922, formulates the broad problem of surge-tank functions, which is to handle in the best possible manner the oscillations which must inevitably occur as the result of the inertia of the water column. The engineer has first to limit the magnitude of the disturbance, and second, to provide for damping it out. Mr. Moody believes that the simple surge tank will accomplish the object of limiting the amplitude of the oscillations if the tank is sufficiently large. Unless relatively very large in dimensions a simple tank will not accomplish the second purpose of damping out the surges, and, in any event, it is not the tank which produces the damping but the friction in the hydraulic conduit. In his opinion, therefore, the so-called simple surge tank is a *surge* tank indeed, since it provides for a continuance of the periodic fluctuations until these are absorbed by friction in the pipe line. If the simple surge tank is not as large as it should be—and this is often the case—it may cause perpetual surging or even augmenting surges.

C. W. Larner[9] (letter dated December 4) objects to Mr. Jakobsen's assumption that an instantaneous load change requires an increase of plant discharge from 1000 c.f.s. to 1500 c.f.s. in a few seconds, and to the further assumption that the 1500 c.f.s. discharge is to be constant in spite of the fact that the head on the plant begins to fall off immediately due to the downward surge in the tank. He believes that such a load increment could not possibly occur in practical operation. This condition is illustrated by a curve in the letter.

Objection is also made to Mr. Jakobsen's alleged argument that the differential tank is not as good as the simple because at each instant during the early part of the surge, the head in the differential tank is lower and the power output less. The writer claims that both surges are identical if we eliminate the element of time. Both start at the same elevation and both end at the same elevation. For every point on the differential-tank curve there is a corresponding point on that of the simple tank. The only difference is that one occurs later than the other.

Mr. Larner suggests that load change be expressed in kilowatts instead of cubic feet per second. He further suggests as the only proper hypothesis for design or comparison of designs, the facts that the discharge of the wheels during the surge will vary and the gates will not be wide open until the bottom of the surge is actually reached. Hence, while it is clear that earlier in the surge the plant could turn a little more power if the gates were opened wider, he does not attach any importance to this because this additional power would have to be dropped a few seconds later.

Minton W. Warren[10] (letter dated December 20) states that if the matters of first cost and interest on the investment are left out, Mr. Jakobsen's statements as to the superiority of the simple surge tank over the differential for the Kerckhoff project are certainly true. He points out that the differential tank is rapidly becoming standard practice and states his belief that in cases where labor, material, and physical conditions are such as are found in the medium-high-head plant in the United States, the differential principle utilized in some form will be found to be an advantage.

Fred W. Ely[11] (letter dated January 31, 1923) in analyzing the reasons which led Mr. Jakobsen to reject the differential surge tank, states that while it is true that during the first 60 sec. the differential tank gives an average of nearly 2000 kw. less than the simple tank, in the next 97 sec. the level in the simple tank is still slowly flowing while that in the differential tank is rising, and therefore the power lost in the first quarter-cycle is gained in the second. The writer believes that the flywheel effect of the rotating machinery could be relied upon to tide over the period during which the short water column in the penstocks is accelerating. Moreover he believes that actually no deficiency of power exists at any time under operating conditions involving constant power; the above is simply predicted on Mr. Jakobsen's condition of constant discharge which the writer claims is impossible. Furthermore, the final quiescent level for the changed conditions will be attained in the differential tank in about one-half the time this level is reached in the simple tank.

While the discussion has been primarily devoted to the argument as to whether, in the face of developments of the differential surge tank, there are any contingencies still left in which a simple tank would be preferable, it has brought out in passing some interesting suggestions as to the problem of surge-tank design to meet special conditions. Thus, Mr. Ely, in his letter referred to above, discusses the case of a tank extending some distance above the ground, where excessive spilling in most cases is impracticable. One plant with which he has had some experience—the Colton Plant of the St. Lawrence Transmission Company at Potsdam, N. Y.—required a tank extending 250 ft. above the ground. A simple tank in such a location would be out of the question, even though this plant falls within the scope of Mr. Jakobsen's classification of low- and medium-head plants. The differential surge tank on this development has furnished satisfactory regulation with no indication of a deficiency of power or fall in speed on suddenly demanded loads.

Letters have also been received from Messrs. P. Wahlman and O. V. Kreuse, but cannot be quoted here because of the lack of space.

[4] Cons. Engr., Niagara Falls, N. Y.

[5] Eng. Dept., Hydro-Electric Power Commission of Ontario.

[6] Rochester Gas & Elec. Corp., Rochester, N. Y.

[7] Civil Engr., New York, N. Y.

[8] Asst. to Vice-Pres., Wm. Cramp & Sons, Ship & Engine Builders, Philadelphia, Pa. Mem. Am.Soc.M.E.

[9] Pres., The Larner Engrg. Co., Philadelphia, Pa.

[10] Eng. Dept., Kalmus, Comstock & Westcott, Inc., Boston, Mass.

[11] Engr. Aluminum Co. of America, Pittsburgh, Pa.

Variations in Design of Milling Cutters

(Continued from page 158)

metal, and energy required per chip on rise in temperature. Aside from this condition and in the case of work where the wide spacing of teeth would cause undue hammering, coarse-tooth cutters should always be used.

Effect of Spiral Angle and of Rake Angle

A large number of runs were made on a set of three 10-tooth cutters having spiral angles of 10, 20 and 30 deg., respectively, and on two 20-tooth cutters having spiral angles, respectively, of 20 and 30 deg. In addition two series of tests with a three-tooth 60-deg. spiral cutter are shown in Figs. 1 and 2. As noted earlier in the report, the metal used in the tests of the first five cutters mentioned was not uniform, so no definite figures are given. The average of the tests, however, shows practically no difference in power required for the different spiral angles. In the case of the three-tooth cutter the authors believe that the lower power requirement is due to the number of teeth instead of the spiral angle.

While increased spiral angles showed no advantage from the standpoint of power, they were of very great benefit in reducing tendency to chatter and in giving smoother action. The vertical pressure between cutter and work was also somewhat less. The end thrust with the 60-deg. spiral cutter was not noticeable as far as the machine was concerned. In general a considerable spiral angle is desirable, the only limitations being end thrust and the danger of burning the sharp corners at the ends of the teeth if the work extends beyond the end of the cutter.

Tests were made with three 10-tooth cutters having rake angles of 0, 10, and 20 deg. and with two 20-tooth cutters having 0 and 10 deg. rake. The increase in rake angle from 0 to 10 deg. caused a saving in power of 20 to 25 per cent, and a somewhat smaller saving was shown on the increase to 20 deg. On the other hand, tendency to chatter increased only slightly between 0 and 10 deg. rake, but became so great as to definitely limit the capacity of the cutter when increased to 20 deg. This limitation seemed to be much more serious than the danger of burning or chipping the edge. Rake angles of 10 deg., therefore, are desirable on cutters, but any considerable increase beyond this point limits the usefulness of the cutter.

Chatter

Chatter rather than the power of the machine is often the limiting factor in milling. For this reason many engineers urge that more rigid machines be built to eliminate this trouble, without realizing that a great deal may be accomplished by the proper choice of cutters. A summary of the elements which affected chatter in these tests is therefore given in the following paragraph.

The most important point in connection with this subject is the fact that tendency to chatter was greatly reduced as the number of teeth in the cutter approached a low figure. On many cuts where it was impossible to eliminate chattering of the twenty-tooth cutter by any reasonable change in speed, absolutely no trouble was experienced with the four- or eight-tooth cutters. Furthermore some trouble was experienced with the eight-tooth cutter on wide and deep cuts at high feeds, but no chattering occurred on any cuts with the four-tooth. Increase in spiral angle also reduces the tendency to chatter, and a combination of wide-spaced teeth and steep spiral angle in a cutter will give the maximum capacity along this line. Moderate rake angles increase the tendency to chatter but little, while large rake angles greatly decrease the capacity of the cutter. The proper consideration of these factors in the choice of cutters will eliminate much trouble in this respect.

Conclusions

Coarse-tooth milling cutters require less power to remove a given amount of metal per minute than fine-tooth cutters. This is true on both wide and narrow work, although the margin in favor of the coarse-tooth cutter is greater on wide cuts. It is also true if both cutters are compared on a chipper-tooth basis.

When compared on a chipper-tooth basis the finish given by the coarse-tooth cutter is better than that by the fine-tooth cutter on account of the closer spacing of revolution marks.

Low-cutting-speed operation of fine-tooth cutters to give a large feed per tooth is objectionable on account of the increased stresses in the machine and holding fixtures.

Fine-tooth cutters are much inferior to coarse-tooth cutters when the relative tendency to chatter is considered.

Moderate rake angles reduce the power consumption and are desirable on all cutters to be used on mild steel. Large rake angles are undesirable due to the tendency to chatter.

The spiral angle has little effect on the power consumption. A considerable spiral angle is desirable, however, because it makes possible the use of fewer teeth, gives smoother cutter action, and reduces the tendency to chatter.

Hence, with the few exceptions noted, coarse-tooth cutters of the type now generally manufactured are superior to fine-tooth cutters for all classes of production work.

U. E. S. Report for 1922

THE report[1] of the treasurer of United Engineering Society for the calendar year 1922 shows a balancing account on December 31, 1922, of $17,014.77, as compared with a balancing account on December 31, 1921, of $26,434.31. The cash on hand as of December 31, 1922, amounted to $138,294.27. Following is a statement of the treasurer's receipts and payments for the year:

RECEIPTS		
Cash on hand January 1, 1922		$14,219.35
From Founders and Associates	$138,294.27	
From societies not in building	17,811.17	
From various accounts	41,994.08	
From Library Service Bureau Photo Department	5,515.06	
From Library Service Bureau Search Department	9,274.28	212,888.86
		$227,108.21

PAYMENTS		
For Operating Payroll	$46,919.31	
For Operating Expenses	37,225.22	
For Equipment, Repairs and Alterations	10,195.56	
For Miscellaneous, Including Taxes	53,144.50	
For Library	56,868.73	$204,353.32
Cash on hand January 1, 1923		$ 22,754.89

SUMMARY OF FUNDS, DECEMBER 31, 1922	
Depreciation and Renewal fund	$133,233.69
General Reserve fund	10,000.00
Library Endowment fund	93,357.40
Engineering Foundation fund	502,074.80
John Fritz Medal fund	3,500.00
Total	$742,165.89

The assets and liabilities as of December 31, 1922, were as follows:

ASSETS		
Property		$1,959,140.67
Land	540,000.00	
Building	1,361,969.51	
Equipment	33,171.16	
Founders' Preliminary Expenses	24,000.00	
Investments—Engineering Foundation		502,074.80
Library		93,357.40
Depreciation and Renewal		133,233.69
General Reserve		10,000.00
Operating Cash	13,350.01	
Library Petty Cash	50.00	
Accounts Receivable	3,869.65	17,269.66
		$2,715,076.22

LIABILITIES		
Founders Equity in Property		$1,959,140.67
Engineering Foundation Fund		502,074.80
Library Endowment Fund		93,357.40
Depreciation and Renewal Fund		133,233.69
General Reserve Fund		10,000.00
Deferred Credits-Unexpended balance in International Dinner Fund	$ 54.89	
Library Income for year 1923	200.00	254.89
Balance in Activity Accounts		17,014.77
		$2,715,076.22

[1] Extracts from treasurer's report for 1922.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities Papers and Proceedings of

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Overdeveloped Coal Industry Cannot Furnish Cheap, Plentiful Coal

THAT the coal industry is overdeveloped is an outstanding definite statement in the first report of the United States Coal Commission. This overdevelopment has been common knowledge for some time, but its authoritative statement by the Commission should focus the attention of the public upon the high prices, faulty transportation, and unsatisfactory labor conditions that have resulted from an excess of two hundred thousand miners and a mining capacity of eight hundred million tons per year, when the annual consumption has never been greater than five hundred and seventy-nine million tons.

The final paragraphs of the report furnish an interesting commentary on this overdevelopment. Quoting from the report:

The way in which to reduce the overdevelopment of the mining industry is fraught with so many complications, not all of which are evident at first glance, that the Commission has not yet had time to ascertain sufficient facts on which to base any recommendations now to be made to the Congress. While it might be expected that in an overdeveloped industry aggressive competition would have driven out mines with high producing costs and forced prices to the consumer down to a minimum, so many such complex factors have operated to prevent the free play of economic forces that a very detailed and comprehensive investigation is required before a valid conclusion can be reached.

The inquiry involves the whole question as to what is best for the people, free competition, government or private ownership, regulation or control in the coal industry. Should the operators in given areas be permitted to combine so that the low-cost mines would furnish the product to the people and the high-cost mines be kept in abeyance to meet an emergency, properly regulated as to price and profit by some governmental agency, or should this prime necessity of life and business be left wholly to open competition in the market? This problem is of so great moment, with reference not only to theories of government but also to the economic life of the Republic, that the view of the Commission must be left to its final report.

The Commission believes that the public interest in coal raises fundamental questions of the relation of this industry to the nation and of the degree to which private right must yield to public welfare. It may be that both private property in an exhaustible resource and labor in a public-service industry must submit to certain modifications of their private rights, receiving in return certain guarantees and privileges not accorded to purely private business or persons in private employ.

In the absence of facts the Commission refrains from comment as to the effect of profiteering, labor difficulties, transportation deficiency, and lack of storage upon high coal prices and unsatisfactory supply. The Report clearly shows the gravity of these problems, however, and points out the many troublesome phases of each which must be investigated before the final report of the Commission can be written. Following is an abstract of the Report which was made public on January 15 and was signed by the entire Commission.

The coal problem begins with a contradiction. Yet, with resources of coal in the ground adequate for the needs of perhaps a hundred generations of Americans, the nation's coal bin is too often depleted and too often the prices paid for coal are much higher than seem warranted by the wealth of coal available. While it is true that a large majority of the states have coal mines within their limits, it is significant that all the anthracite comes from a narrow area of 480 square miles in eastern Pennsylvania and 93 per cent of the bituminous coal comes from three major areas: the Appalachian region, extending from Pennsylvania to Alabama, the greatest storehouse of high-rank coal in the world; the Eastern Interior region, comprising Illinois, Indiana, and Western Kentucky; and the Western Interior region, extending from Iowa to Arkansas and Oklahoma.

The coal-mining industry, in point of numbers employed, outranks any single manufacturing industry and stands next to transportation and agriculture. Approximately three-quarters of a million men are employed in this industry, of whom 90 per cent work underground. The capital invested, according to the rough figures of the census, is $2,330,000,000, of which $430,000,000 is invested in the anthracite region and the remainder in the bituminous fields. There are only 174 producers of anthracite and eight of these control over 70 per cent of the annual output, while there are at least 6000 commercial producers of soft coal, to say nothing of thousands of wagon mines and country coal banks. These producers operate 9000 commercial mines.

The bituminous output is consumed approximately in the following percentages: Railroads, 28; Industrials, 25; Coking, 15; Domestic, 10; Iron and Steel, 7; Public Utilities, 7; Export, 4; Mines, 2; Bunkers, 2. The coal industry does not end at the mines. Some 180 railroads take the coal at the mine mouth and transport it to thousands of destinations. Because the railroads are the largest customers of the bituminous industry, and because coal—anthracite and bituminous—constitutes one-third of the railroad's freight, the problems of the two are closely interwoven and their interests interdependent.

Nor does the coal industry end with transportation. To connect the thousands of producers, big and little, with more than 90,000 buyers of carload-lot coal scattered over 48 states, requires a widespread system of wholesale marketing. There are some hundreds of large wholesalers and a much greater number, perhaps 3500 in all, of smaller middlemen. Like the business of running mines, the business of selling has its problems and, like mining, it has also its abuses. The final link in the chain of coal supply is the retailer, who receives coal in carload lots from car or yard storage and delivers it in smaller quantities to the consumer. There are some 38,000 retail coal dealers, most of them conducting a small business. They handle about 130,000,000 tons of coal, or 14 per cent of the bituminous and two-thirds of the anthracite produced. Combined charges of the railroads, the wholesaler, and the retailer in most localities exceed the price of the coal at the mines. Therefore it is readily seen that the problem whether the transportation and marketing charges are just and fair is of the utmost concern to the consumers of coal.

It has been suggested to us that one of the causes of high prices of coal is profiteering. There has been profiteering in the sense that grossly exorbitant profits have been taken at times by many operators, brokers, and retailers; profits that have been disproportionate to the cost of the coal or the service rendered or the risk incurred. But this Commission has not obtained the figures for the past ten-year period specifically required by the Act in order to settle this question.

There can be no doubt that two of the three periods of high prices since 1916 have been caused largely by labor troubles. In the first period of scarcity—August, 1916, to March, 1918—there were no strikes of consequence and therefore some other explanation of the high prices and distress must be found. The second period of runaway prices, November, 1919, to late in 1920, was originally caused by a nation-wide strike of miners beginning November 1, 1919. In this case the shortage created by the strike was aggravated by difficulties in transportation resulting in part from severe weather and in part from a strike of railway switchmen, and was further intensified by an unprecendented demand for export and by boom times at home. In the third period of shortage and high prices, from which we have not yet emerged, the primary cause was a nation-wide suspension of mining, involving practically all union men, which closed the anthracite region completely and shut down two-thirds of the capacity in the bituminous fields of the United States and Canada.

An opinion commonly expressed before the Commission is that the primary cause of scarcity and high prices of coal is transportation deficiency. There have been recurring periods of "car shortage," and such periods have generally been accompanied by high prices of coal. There are many other causes for the inadequacy of transportation beside the absence of cars, such as lack of motive power, congestion of yards, terminal facilities, or gateways, single tracks where double tracks are needed, inability to coördinate movement of boats and cars at ports, strikes of railway labor, and severe winter storms temporarily blockading traffic. The so-called "car shortage" is not always due to insufficient coal-carrying equipment alone. In part it has been due to an overload upon the transportation system beyond what that system could reasonably or properly be expected to bear.

We find that in the bituminous industry since 1890 the mines have averaged over the country as a whole, only 213 days out of a possible working year of 308 days. These averages, of course, show nothing as to the relative annual earnings of individual miners or their individual opportunity to work. In 1920, a year of active demand, the average time worked was only 220 days,

and in 1921, the year of depression, it dropped to 149 days, with many districts showing a figure much below this average. Over a long period comparatively little of the time lost has been on account of strikes and that in the years when there are no strikes the aggregate time lost from all causes is about as great as in those when strikes occur. In the twenty-three years over which the statistical record of strikes extends, the time lost because of strikes has averaged 9 days a year, or less than 10 per cent of the time lost for all causes combined. Short working time is the result of overdevelopment in the industry. There are more mines and more miners than the needs of the country require.

Although the country has never been able to absorb in a year more than 579,000 000 tons of bituminous coal, the present capacity of the mines is well above 800,000,000 tons.

The steady increase in the army of bituminous coal miners during the last four years, notwithstanding a lessened demand for their product is also a fact that stands out in the statistical records furnished the Commission by the U. S. Geological Survey. In 1918, the year of maximum coal output, when 579,000,000 tons were mined, 615,000 men were employed in the bituminous coal mines, nearly 622,000 the next year, over 639,000 in 1920, and in 1921, 663,000 mine workers were employed in producing about 416,000,000 tons. To get a year comparable in soft-coal output with 1921 we have to go back to 1910, when 417,000,000 tons were mined, and it is significant that in that year less than 556,000 mine workers were employed—or about a million more tons of coal with 100,000 fewer miners.

The Commission is convinced that there can be no permanent peace in the industry until this underlying cause of instability is removed. Diverse causes have apparently promoted overdevelopment and inquiries are in progress as to the relative importance, among others, of the following: The policy of railroads toward encouraging the opening of new mines and new mine fields as sources of revenue; car distribution rules that permit, if they do not encourage, larger capacity than the market obviously requires; the opening of new mines by large consumers; the establishment of freight rates that encourage the development of new fields; shifts in centers of consumption that abandon old fields and encourage new fields; the difference between union and non-union wage costs; large-scale suspensions in the unionized fields; and irregularity of demand.

American Railroads

THE PROBLEMS of our American railroads should be considered with two thoughts clearly in mind, both of them of intimate relation to American industry and engineering generally. First, our railroad system is the fundamental in a national scheme of production and distribution; and second, the railroad industry with an investment conservatively estimated at twenty billion dollars, has an annual purchasing power, when in healthy condition, of over a billion dollars. The factors that impair this purchasing power immediately reduce industrial activity.

The relation between transportation—and in particular, railroad transportation—and production was effectively discussed by Julius H. Barnes, president of the Chamber of Commerce of the United States, before the American Society of Civil Engineers at its recent annual meeting. While Mr. Barnes considered motor-truck and water transportation, he was careful to emphasize that our railroads remain always the chief channel of transportation. He was not able to give definite figures, but he did point out that the ultimate effect of the increasing ability of the individual to produce, his increasing buying power and his ever-widening demand for goods will result in the not-far-distant future in the serious embarassment of our transportation scheme. While the railroads have, during the past two decades, kept step with the increased transportation needs of the country, Mr. Barnes called attention to the fact that any material expansion of transportation service must require large additional capital investments. It is probable that some single- and even double-track lines are approaching the maximum load possible for the capacity of their present rails, and any substantial increase means at once new roadbeds. The service limit of existing terminal facilities is even nearer to the maximum possible, largely because not enough money has been spent on terminal improvements during the last fifteen years.

There is a general acceptance of the principle of regulation of transportation by railroads, but it is Mr. Barnes' belief that in the past this regulation has been over-rigid and shortsighted. It destroyed the current earning power of the railroads and undermined their credit, leaving them unable to adequately expand their facilities with the increasing tonnage of the country and in anticipation of future growth. It is becoming clearer and clearer that enlightened self-interest requires a fair and even generous interpretation of regulation of these great arteries of commerce, but before large investments are made in terminal or special facilities and equipment of railroads, there should be a comprehensive survey of the future of transportation in all its various forms, and then intelligent preparation to utilize them in caring for the expanding commerce of the country.

The other aspect of the railroad problem in which the railroads figure as an industry that can spend money and provide business for others, is considered in an editorial in The New York *Times* of February 7, 1923. According to this, railway construction would rival building construction if the companies were helped or even let alone. Chicago is planning a union station which will exceed in size either of those in New York. The Illinois Central alone needs to spend forty-five million dollars. All railroads would spend the billion they should spend in the aggregate to give necessary facilities, if they were allowed reasonable profits with which to solidify their credit. It would be an enormous relief to the industrial situation if the railroads were permitted to finance themselves. The vitalizing of twenty billions of capital would strengthen the domestic financial situation quite as much as foreign purchases of our excess food production stimulate our farmers. Railroad consumption forms a larger proportion of the domestic iron and steel demand than the foreign demand does of the total of our agricultural products.

In this connection, however, it should be remembered, that although in 1907 the railroads were the largest consumers of steel and iron, today sheets, plates and pipe for general industrial use are the major products of the iron and steel industry, this of course being largely due to the fact that the railroads did not keep up with the country in their expansion.

There are many indications, however, that the outlook for the future is brightening. After all it was not lack of capital in the country that prevented the development of the railroads, but lack of good will in certain powerful groups and resulting lack of confidence in the future of the railroads among the general investing public. There has been of late a vigorous effort to reëstablish good will toward the railroads and a healthier spirit of coöperation is now being exhibited by the public generally, and by the governments of the various states in particular. Regardless of what our individual opinions concerning railroad management may be, the country needs successful and efficient railroads perhaps more than it needs anything else, and every effort within reason should be promptly directed toward making them both successful and efficient.

International Coöperation in Research

IN A RECENT communication William Henry Patchell, vice-president of the Institution of Mechanical Engineers of Great Britain, and a recent visitor to America, made a plea for the closer coöperation in research of the engineering societies of English-speaking countries. During his visit to America Mr. Patchell found that investigations on similar subjects were occupying the attentions of both British and American engineers, notably the work in steam, an investigation on steam flow through nozzles, and the codes for testing engines and boilers. Mr. Patchell suggested that an immediate solution might be the appointment of corresponding members by The American Society of Mechanical Engineers and the Institution of Mechanical Engineers on the Steam Nozzles Research and Steam Research Committees, respectively. Such contact would expedite the formulation of codes and provide opportunity for international criticism which would clarify the field and look toward the possible adoption of international codes and correlated international research.

It goes without saying that any relations set up between national engineering societies will be helpful in cementing permanent affiliations.

American engineers will gratefully receive this fortunate expression of coöperation from Mr. Patchell, an outstanding man in his profession in England, having been honored not only by being chosen as vice-president of the Institution of Mechanical Engineers, but also as vice-president of the Institution of Electrical Engineers. American mechanical engineers will recall his leadership in the use of large boilers at the Bow Street Station, London, in 1905 and his memorable paper dealing with superheater experiments in 1896.

The Federated American Engineering Societies

AN OUTSTANDING result of the recent annual meeting of the American Engineering Council was the quickening of the sense of responsibility in each member of the Council for the establishment of a more complete understanding of the aims and objects of The Federated American Engineering Societies in the minds of the individual members of the constituent organizations. That the Federation is dependent for its growth and success upon the unswerving loyalty and increased activity of each Council member was emphasized by President Cooley, doubly stressed by Executive-Secretary Wallace, and touched on again and again during the two days of the meeting.

The Council adopted a resolution "That it shall be the established policy of the F.A.E.S. to advise its member societies promptly and as fully as obligations of confidence will permit, of the consideration or the undertaking of all matters of material interest and to seek and obtain the advice and counsel of the member societies so far as that can be done without delay or detriment to the matter under consideration." This resolution was proposed by John Lyle Harrington as chairman of the A.S.M.E. delegation to the Council. The debate lasted over two hours. While its adoption puts a responsibility upon the American Engineering Council to advise and consult, there is a still greater responsibility upon the delegates to the Council and the governing bodies of the constituent societies to organize so that the desires and opinions of the individuals making up the member organizations may be available promptly for the guidance of the American Engineering Council and its Executive Board. Gladly shouldering this responsibility, the A.S.M.E. delegates to the American Engineering Council during the coming months will address individual members of the Society and Local Sections officers for expressions of opinion on various activities that the F.A.E.S. is carrying on, and will solicit suggestions for new activities for The Federated American Engineering Societies.

Engineers must grasp the remarkable opportunity offered by the F.A.E.S. to demonstrate the leadership of their profession in solving the tremendous economic and industrial problems facing this country.

L. P. Alford.[1]

The Engineer in Public Life

THE KEYNOTE of the annual meeting of the American Engineering Council was struck by Dean M. E. Cooley, in his presidential address, as follows: "We are, I feel, entering upon a new era. The engineer, not so much in the technical as in the social sense, is about to take that part in the world which rightfully is his. I am speaking not of civil engineering, mechanical engineering, chemical engineering, electrical engineering, or any other branch of engineering, but of the engineering profession as a whole........After fifteen months of service as president of the Federation I am convinced that the opportunities of the engineer are very great. I have the utmost faith that the engineering profession of this country and, through affiliation with foreign organizations, of the world, can bring to pass a new epoch in man's history."

This attitude has recently been expressed by the technical press, as shown in the following extracts.

Public Service and the Engineer

"Five engineers constitute the personnel of a rapid-transit commission brought into being at Detroit. Engineers as such will take satisfaction in the appointment. Formerly these engineers would have been employed as members of the staff, but here is public recognition that technical ability and executive ability may be found in the same man. There is a tendency for engineers to think of themselves as representing a quality of mind not possessed by others. It is true they are not so bound by tradition as are many other members of the community and they think in terms of the future as well as the present, in a day of industrial marvels. Also they are growing numerically strong, for the broadening range of engineering undertakings has held out promising opportunities, and the conspicuous successes the best brains have won in industrial life and in public places have brought high credit to the profession. Promotion activities like those of The Federated American Engineering Societies have done their part in bringing such recognition, and so has the equipment the average engineer now brings to his task."—*Iron Age.* February 1, 1923, p. 361.

The Engineer in Civic Life

"Recent developments (referring to the appointment of Prince Caetani as ambassador from Italy, to the adoption of American management methods by Czechoslovakia, and to the work of the F.A.E.S.) indicate the occurrence of two interesting events—the realization by the public of the service it can command from the engineer and the awakening of the engineer to the fact that he can be a valuable public servant.

"'Engineering thinking' and 'the engineering approach' may perhaps have fallen to the status of mere catchwords, but there is nevertheless a real need for the methods of the engineer in public office, and the more of him this country can induce to enter its service, the better."—*American Machinist,* January 25, 1923, p. 166.

The same issue of the *American Machinist* (p. 158) quotes from an address by Dr. J. A. L. Waddell, a consulting engineer of New York City, before the engineering students of the University of Barcelona, with the comment that although the engineer has begun to interest himself in politics and to make himself felt in this field, there is still much to be desired from those engaged in all classes of engineering work. Dr. Waddell's statement is as follows:

> Every individual should pay proper attention to his duties as a citizen of the country in which he resides Engineers in America are great sinners in this particular; and the result is that our profession has very little to say regarding the government of our country. In the Administration, the Senate, and the House of Representatives at Washington engineers are generally conspicuous by their absence. This is a condition that should be corrected as soon as possible, for the benefit not only of our profession but also of that of the country, because who is there so competent in thought and action as an engineer?
>
> In European countries, I believe, engineers take a more prominent part in politics than they do in the U S. A.—for instance, in Italy there are twenty-three engineers who are members of parliament. What the conditions in Spain are I do not know; but I notice that the Alcalde of Barcelona is a distinguished engineer.

In an editorial on The Federated American Engineering Societies in *Power* for January 30, 1923, Fred R. Low makes the following pertinent statement:

"The orderly reorganization of a system of diversified and often conflicting self-centered interests into an interlocking system of production, transportation and distribution devoid of wasted effort and lost motion; the impressment of the necessary regulative and directional forces without cramping initiative and motivating purpose; must be done against the inertia and resistance of established privilege and with the repression of unreasoning radicalism.

"The belief is growing that the unemotional, analytical, practical engineering type of mind and of man must be looked to to bring this about."

Indiana Engineering Society

The twenty-ninth organization to join the F.A.E.S. is the Indiana Engineering Society, comprising a membership of nearly 400. The object of this association, which has its headquarters in Indianapolis, is "the encouragement of professional intercourse between the engineer and surveyors of the State of Indiana, and the advancement of its members in scientific research in the various branches of engineering."

While public service is not included in this clause from the constitution of the Society, Indiana has ever had the coöperation of this group of engineers in such matters of public concern as flood prevention, sewerage, road construction, and water works. The president of the society is W. H. Elliott and its secretary is Charles Brossman.

[1] Vice-Chairman, A.S.M.E. Representatives on American Engineering Council.

Engineering and Industrial Standardization

Standardization of Methods of Testing Wood Now Under Way

INNUMERABLE misunderstandings and disagreements concerning strength of lumber and timbers, and such accidents as grow out of miscalculation of the strength of various kinds of lumber, should be greatly reduced as a result of the standardization of methods of testing wood, recently undertaken by the many interests involved, under the auspices of the American Engineering Standards Committee.

The U. S. Forest Service and the American Society for Testing Materials have been appointed joint sponsors for this undertaking, and 16 additional organizations are represented on the sectional committee which is to make an intensive study of the subject.

The scope of the committee's activities embraces the standardization of physical (including mechanical) tests of wood specimens. Of immediate importance is the application of these tests to (*a*) small clear specimens, and (*b*) structural timbers. The most important desideratum involved is the establishment of standard practice in testing wood which will make data obtained at different sources of the broadest possible value and insure the attainment of comparable results.

L. J. Markwardt of the Forest Products Laboratories at Madison, Wisconsin, has been elected chairman of the sectional committee and Prof. M. O. Withey, Professor of Mechanics, University of Wisconsin, secretary.

Automobile Headlight-Testing Specifications Approved by A.E.S.C.

ONE of the tribulations of the touring motorist—the hopeless attempt to comply with the automobile headlighting regulations of all states through which he passes on his trip across the continent—will be removed as soon as the various state motor-vehicle departments have all adopted the Specifications of Laboratory Tests for Approval of Electric Headlighting Devices for Motor Vehicles which has just been approved by the American Engineering Standards Committee. Nine states have already indicated that they will adopt the specifications, while in three they are already in effect.

These specifications were submitted to the A.E.S.C. by the Illuminating Engineering Society. This organization and the Society of Automotive Engineers have been appointed joint sponsors for any revision and further development of the code which may be necessary. Approval of the specifications was recommended to the American Engineering Standards Committee by a Special Committee which had been appointed to investigate their practicability and acceptability. This Committee, of which David Van Schaack, vice-president of the National Safety Council, was chairman, was made up of representatives of the automobile manufacturing industry, automobile accessory manufacturers, the officials of motor-vehicle regulatory bodies, insurance companies, safety organizations, technical societies, and of the U. S. Bureau of Standards.

Safety Code for Power Presses and Foot and Hand Presses

THE use of power presses and foot and hand presses for stamping and forming pieces of metal and other material has grown so rapidly, and the loss of hands or fingers on these presses as commonly operated is so frequent, that this hazard has become one of the most serious mechanical problems in accident prevention.

This code is one of a number of safety codes which have been or are being formulated under the general auspices of the American Engineering Standards Committee. One purpose of the code is to serve as a guide to state authorities. Part I includes such requirements as may properly be enforced by a state industrial commission or labor department such as the location and installation of presses, feeding and removing material, making and setting of dies, and operating rules. Part II contains illustrated descriptions and discussions of press hazards and the methods that have been used to remove or protect against them. Both parts are fully illustrated.

This code, sponsored by the National Safety Council, was formulated by a committee of twenty-one men, including two representatives of the manufacturers of presses, five users of presses, one representative of employers, five governmental bodies, five specialists in the subject of power-press operation and safety, and three insurance representatives. Mr. C. B. Auel, manager, employees' service department, Westinghouse Elec. & Mfg. Co., Pittsburgh, Pa., was Chairman of the Sectional Committee, and Mr. S. J. Williams, chief engineer, National Safety Council, 168 N. Michigan Ave., Chicago, Ill., was its secretary. For copies of this code address the National Safety Council.

Building Code Committee Issues First of Its Series of Reports

INVESTIGATIONS by a Congressional Committee during 1919 and 1920 disclosed the fact that existing building laws through variations and inconsistencies of their provisions and through unduly restrictive or expensive requirements, were operating to prevent needed activity in the building industry. That these conditions might be remedied, a committee of experienced engineers and architects was organized by Secretary Hoover, to investigate building practice and code requirements and to prepare standard building regulations based on the latest and best information, which might be recommended to cities and states adopting or revising building codes.

In order that its recommendations might have sound bases of information and opinion, the committee is coöperating with nearly one hundred engineering and architectural societies, builders' exchanges, and industrial organizations producing building materials. Special questions also are referred to large groups of individual engineers, architects, building officials, to the Bureau of Standards, and to others whose experience qualifies them to discuss such subjects.

Owing to the pressing need for dwelling houses the first report of this Committee only presents recommendations for the construction of one and two-family houses having exterior walls of solid or hollow masonry, concrete, and frame, the latter including veneer and stucco surfaces.

The Committee recommends that building codes permit 8-in. solid brick and 6-in. solid concrete walls for $2^1/_2$ and 3-story dwellings accommodating not more than two families each; that 8-in. hollow building tile, hollow concrete block, or hollow walls of brick (all rolok) shall not exceed 20 ft. in height to the gables; and that frame construction be limited to $2^1/_2$ stories. Metal lath and plaster on wood studs properly firestopped is approved for party and division walls, but at least every alternate wall in row houses must be 8-in. solid brick or concrete or 12-in. hollow building tile, concrete block, or hollow wall of brick.

The report recommends revised working stresses for timber used in dwellings, based on investigations of the U. S. Forest Products Laboratory. Live loads to be required as bases for design are 40 lb. per sq. ft. for floors of wood, and 30 for those of monolithic type, or of solid or ribbed slabs. Foundation walls of brick are required to be 12 in. thick for excavated enclosures, and similar concrete walls shall be as thick as the walls they support but not less than 8 in. Special hollow building tile 12 in. thick is permitted for foundation walls of frame buildings. Detailed recommendations are given for firestopping and chimney construction, also for treatment of built-in garages.

Subsequent reports will deal with the construction of multi-family dwellings, hotels, clubs, office buildings, stores and other mercantile buildings, factories, work shops, amusement places, churches, institutions, schools, public buildings, garages, and other non-residential buildings.

The Committee is composed of the following members: Ira

H. Woolson, Chairman, consulting engineer, National Board of Fire Underwriters, New York City; Edwin H. Brown, architect, Minneapolis, Minn.; William K. Hatt, professor of civil engineering, Purdue University, Lafayette, Ind.; Rudolph P. Miller, formerly supt. of buildings, New York City; John A. Newlin, in charge of section of timber mechanics, Forest Products Laboratory, Madison, Wisconsin; Ernest J. Russell, architect, St. Louis, Mo.; and Joseph R. Worchester consulting engineer, Boston, Mass.

This report, comprising 100 pages and thirty illustrations, may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. Price 15 cents.

Bureau of Standards Conducts Investigation on Welded Pressure Vessels

Meagerness of scientific data on which to base proper requirements for safety without placing unjust restrictions on the use of welding has raised a difficult problem for the Boiler Code Committee of The American Society of Mechanical Engineers in its effort to draw up a code to govern the construction of unfired pressure vessels. However, with the coöperation of the American Bureau of Welding, which is the advisory committee on welding research for the American Welding Society and the National Research Council, a Pressure Vessel Committee was appointed to coöperate with the Boiler Code Committee and a series of tests was arranged to be carried out by the United States Bureau of Standards. Eight manufacturers placed forty tanks at the disposal of the Committee and provided funds for the test. A hydrostatic and hammer test was finally decided upon to determine whether a vessel was safe for the purpose for which it was designed.

The shells of most of the tanks were 6 ft. long and 2 ft. in diameter, and made of $^3/_8$-in. mild steel plate. Both electric and oxy-acetylene welding were used. The hydrostatic and hammer test developed that the welded pressure vessel, according to the regular formulas for working pressure, has a factor of safety of about 6.

A remarkable feature of this undertaking is the rapidity of accomplishment. The first meeting of the committee was held in New York on August 17 last, and a plan outlined. The tanks called for in the program were immediately built by manufacturers distributed widely (one of them on the Pacific Coast), and shipped to the Bureau of Standards in Washington. Most of the tanks arrived by the first of December. Under the supervision of Dr. H. L. Whittemore, Chief of Section VII-1, Physical Tests of Structural Materials Division, who is also chairman of the Committee, testing was started December 4 and carried on continuously to January 10. Many visitors, including members of the Boiler Code Committee, insurance inspectors, tank manufacturers, American Welding Society and National Research Council, have witnessed the tests.

A complete report will appear in the April issue of Mechanical Engineering.

Boiler-Furnace Refractories

The subject of Refractories and their relation to the furnace problem of modern central stations drew an interested audience to the meeting of the Metropolitan Section of the A.S.M.E. in New York City on January 23. Kenneth Seaver[1] in a very interesting talk, told of the problems of the manufacturer of firebrick and pointed out the manufacturing difficulties that must be overcome by proper furnace design and construction. Mr. Seaver emphasized that the main dependence of the power-plant operator is ordinary firebrick, for silica brick, which is suitable for high temperatures, such as are achieved in metallurgical work, is unstable for boiler settings on account of its contraction and expansion in the lower temperature ranges. Long freight hauls for firebrick are uneconomical and therefore brick made from clay handy to the user must be employed. This makes standardization of material very difficult, but the manufacturer, by study of the clays available in each district, may obtain the best results by compounding or other treatment. The operating engineer requires uniform sizes of firebrick, as thin joints, which seem essential to long furnace life, are impossible where firebrick vary in thickness. Mr. Seaver pointed out that variations in sizes are due only partly to the effect of heat in the kiln and mostly to the effect of variation in pressure in the different layers. He told of methods being employed, by certain power plants in the construction and repair of furnaces, such as spraying the inside of the furnace with a half-inch layer of high-temperature cement, or the use of relieving arches, or, by slight changes in form or location, correcting improper draft distribution. In the discussion the importance of uniformity was again emphasized by firebrick users. Edwin B. Ricketts[1] stated that the troubles due to high furnace temperatures might be solved by locating passages in the walls through which air may be passed on its way to the combustion chamber.

[1] Chief Engineer, Harbison-Walker Refractories Co. Pittsburgh, Pa. Mem. Am.Soc.M.E.

[1] Asst. Chief Operating Engineer, New York Edison Co. Mem. Am.Soc. M.E.

MEETINGS OF OTHER SOCIETIES

American Institute of Chemical Engineers

Historic and industrial Richmond was headquarters for the fifteenth annual meeting of the American Institute of Chemical Engineers, held December 6 to 9, 1922, inclusive. The excursion program included trips to points made famous by the Civil War as well as to modern industrial plants. A large delegation visited the Virginia-Carolina Chemical Company's plant, where sulphuric acid, acid phosphate, and mixed fertilizers are made. Materials handling has been reduced to a minimum in this plant; transportation is carried out on elevated tracks by means of an electric engine and also by means of electric cranes on either side of the building. At Hopewell, which now has a population of some 9000 and contains a number of thriving industrial plants, the Hummel-Ross pulp factory was inspected. The Richmond Cedar Works, the Richmond Car Works, the Standard Blotting Paper Co., and other industrial plants were also visited. An inspection of the tobacco factories was preceded by an instructive address by T. M. Carrington, president of the Tobacco Association of the United States, on the American tobacco industry. Of special interest were the automatic packing and wrapping machines used in the factories.

The technical program of the meeting contained a number of papers of general interest. A. E. Marshall, of Baltimore, Md., spoke on the use of pyrex glass as an engineering material. Dr. J. R. Young, Mellon Institute, outlined the development of asbestos-protected metal. Three papers on the absorption of gases in towers were presented: F. C. Blake, of the Du Pont Company, discussed the resistance of packing to fluid flow and W. B. Van Arsdale, of the Brown Company, and Prof. R. T. Haslam, Massachusetts Institute of Technology, the effect of rate of flow on absorption. Among other topics considered were the various uses of wood and concrete in chemical industries, waterproofing concrete, and stirrer performance.

American Petroleum Institute

The third annual meeting of the American Petroleum Institute was held in St. Louis, Mo., December 6, 7, and 8, 1922. It was preceded by a meeting of the Association of Natural Gasoline Manufacturers, making a four-day convention for the consideration of problems of the oil industry, a number of which involve mechanical engineering. Among the subjects discussed at general and group sessions were standardization of equipment, internal-combustion engines, natural gasoline as a motor fuel, and the relation of the "knock" to the gasoline problem.

Under the general topic of standardization, simplification and improvement of oil-drilling methods and equipment a number of important papers were presented. S. F. Speller, National Tube Co., discussed the physical qualities of pipe, with special reference to iron, bessemer steel, and open-hearth steel, and the activities of the Mid-Continent Oil Gas Association regrading pipe for deep-well drilling were recounted by J. Edgar Pew, of The Sun Co. Drilling

equipment, from the point of view of the essential qualities and analysis of raw materials entering into its manufacture, and also the value of heat treatment, was the subject of an address by Prof. F. F. McIntosh, of the Carnegie Institute of Technology. Papers on the standardization of tool joints, rig irons, and cable tools were followed by a general discussion of the question, What Does the Oil Industry Wish to Do About Standardization? This subject of standardization in the oil industry was also discussed at one of the sessions from the points of view of the engineer, the field man, and the supply manufacturer.

Several group sessions were devoted to the subject, What is Good Gasoline? Dr. S. W. Stratton, of the Bureau of Standards, gave the answer as so far formed by the joint research program of the Bureau and the oil and automotive industries. Thomas Midgley, Jr., General Motors Research Corporation, pointed out the relationship of "knock" to the gasoline problem and discussed the remedy for knocking. A paper on the use of natural gasoline in motor fuel was presented by O. P. Kenney, of the Tide Water Oil Co., at a session of the Association of Natural Gasoline Manufacturers. Henry L. Doherty, New York, gave his interpretation of the problem of heavy fuels for internal-combustion engines.

Society of Automotive Engineers

An unusual educational opportunity was afforded automotive engineers and executives during the week of January 8, when two automobile shows and the annual meeting of the Society of Automotive Engineers were held in New York City. S.A.E. members attending the annual meeting were guests at both the National Automobile Show and the Automobile Body Builders' Show, and it is more than probable that their inspection and study of new developments displayed at the shows gave impetus to their discussion at the sessions of the annual meeting.

There were seven technical sessions, two on body engineering, and one each on engine cooling, aeronautics, fuels, detonation, and research. One of the most novel ideas brought out during the meeting was a new all-fabric closed body described in a paper on Cheaper Closed Body Construction, presented at a body engineering session, by George J. Mercer, of Detroit, Mich. This body consists of a wire-covered wood frame on which are applied a layer of heavy buckram and a covering of highly finished fabric. Mr. Mercer outlined the merits of the fabric body and stated that he expected to put it on the road in the near future in order to determine its durability.

At the same session J. B. Davis, of the Standard Textile Products Co., New York, N. Y., described methods of testing leather substitutes and top material recently developed by his concern in coöperation with the Bureau of Standards and the Society for Testing Materials.

Testing automobile finishing varnish was the subject of a paper by L. Valentine Pulsifer, chief chemist, Valentine & Co., New York, N. Y. Mr. Pulsifer stated that the three most important factors in estimating the service-giving qualities of varnish are elasticity, moisture resistance, and film thickness. Mr. Pulsifer performed actual tests for these qualities and discussed the testing of varnish qualities in general.

The fourth paper presented at the body engineering sessions was by F. F. Murray, advisory mechanical engineer, Hardwood Manufacturers' Institute, Chicago, and dealt with the needless waste of hardwood lumber in the automotive industry. He pointed out that the cost of body production could be considerably reduced by a revision of specifications for grading, and commended the work of the Central Committee on Lumber Standards which is endeavoring to produce a new and scientific grading schedule that by common accord will establish a lasting instrument to be entitled the American Lumber Standards.

A symposium of papers on commercial airplane design was held on the evening of January 9. Prof. E. P. Warner, Massachusetts Institute of Technology, named economy, safety, speed, and comfort as qualities which the finished plane should possess, and discussed the relative importance of these factors. Other speakers spoke of the obligation which the Government has in carrying forward development, and possibilities of commercial aviation, emphasizing the necessity for "selling" the public as to its safety and practicability.

At the detonation session Thomas Midgley, Jr., of the Dayton Research Laboratories, outlined the prevailing theories of detonation and described experiments which he has conducted to determine the laws governing detonation. S. M. Lee and S. W. Sparrow, of the Bureau of Standards, described methods used and results obtained in two investigations of fuels for high-compression aviation engines. A paper by J. H. Hollaway, H. A. Huebotter, and G. A. Young, all of whom are connected with Purdue University, discussed their research work into the operation of internal-combustion engines under comparatively high compression on ordinary gasoline without detonation.

Reports on fuel-volatility research at the Bureau of Standards, and on the work of the research department of the S.A.E., especially in regard to fuels, were presented at a research session of the meeting. At the fuel session, papers on the effective volatility of motor fuels, the proper utilization of natural gasoline, and a survey of gasoline and kerosene carburation were presented. The latter paper gave a general discussion of gasoline carburation requirements, the use of petroleum fuels, and reasons for the present wastage of fuel by improper carburation.

An interesting paper on aircraft-engine practice as applied to air-cooled passenger-car engines was presented at the engine-cooling session. This article showed wherein the automobile designer and engine builder can profit by the use of practice developed for air-cooled aircraft engines and contained a detailed discussion regarding cylinder design and performance, inclusive of valve location, type of finning, and form of cylinder head.

Elisha Lee, vice-president of the Pennsylvania Railroad, was the chief speaker at the annual dinner of the society. His subject was motor transport and our railroads, a problem in coördination. Herbert W. Alden, chief engineer, Timken-Detroit Axle Co., newly-elected president of the society, reviewed its progress during 1922 and announced that emphasis during 1923 would be laid upon production engineering.

American Society of Civil Engineers

The conferring of five honorary memberships, the election of Charles F. Loweth as president, meetings of four new technical divisions, reports of technical committees, an all-day excursion to Bethlehem, and technical sessions on engineering education, engineering research, and city planning—all these were outstanding events in the seventieth annual meeting of the American Society of Civil Engineers, held in New York January 17, 18, and 19, 1923.

The recipients of honorary memberships were Leon-Jean Chagnaud, Paris, noted for his subaqueous and subterranean excavation work; Sir Maurice Fitzmaurice, London, internationally prominent through his achievements in bridge engineering and irrigation and drainage work; Clemens Herschel, New York, past-president of the A.S.C.E., the inventor of the venturi meter; John Frank Stevens, New York, railroad engineer and well known for his work as chief engineer of the Panama Canal; and William Cawthorne Unwin, London, engineering educator and authority, honorary member A.S.M.E. and recipient of the Kelvin Medal in 1921.

Charles F. Loweth, who succeeds John R. Freeman as president, has been chief engineer of the Chicago, Milwaukee & St. Paul Railway since December, 1910. He has been active in the work of the society, serving as director and vice-president, and rendered valuable service as its representative on Engineering Council.

With the formation of four technical divisions, the A.S.C.E. has joined the ranks of those large engineering organizations which are recognizing the potentialities of such specialized branches. The technical division on sanitary engineering, which had previously been organized, held its first general meeting on January 16. H. P. Eddy, consulting engineer, Boston, Mass., read a paper on the Present Status of Sanitary Engineering and made valuable suggestions as to the aims of the division. Organization meetings of the three other divisions, on irrigation engineering, highway engineering, and power, were held on January 19. Tentative organizations and plans for procedure were drawn up and lines of work to be carried on by the divisions were discussed.

An all-day excursion to Bethlehem on January 18 included inspection of the new Hill-to-Hill bridge, which is 62 ft. wide and, with its approaches, about 6000 ft. long; the works of the Bethlehem Steel Company, especially the open-hearth department, the rolling

mill, and the fabricating shops; and the John Fritz Laboratory at Lehigh University.

Among the committee reports which were presented was the third report on stresses in railroad track, covering a study of curved track; the final report on bridge specifications, which differs from other current specifications in that it is shorter and restricts itself to general considerations, leaving details to the individual engineer; and a summary of tests of impact in highway bridges.

At the session on engineering education Charles F. Scott, professor of electrical engineering, Sheffield Scientific School, reviewed what is being done by various societies for the promotion of engineering education, and outlined the new project of the Society for the Promotion of Engineering Education; this was described in an editorial by him in the February issue of Mechanical Engineering. The Outlook of the Engineering Colleges of the Middle West was the subject of an address by William G. Raymond, dean of the College of Applied Science, State University of Iowa. A paper by Magnus W. Alexander, managing director of the National Industrial Conference Board, read by Mr. Trowbridge, a member of his staff, emphasized that the engineer, animated by his constant spirit of inquiry, should guide industry in basing its work upon ascertained fact and experience. John L. Harrington, president of the A.S.M.E., urged the coöperation of the national societies in a plan for a general undergraduate engineering society, directed by the students themselves rather than by the national societies or faculties.

The speakers at the research session were Arthur N. Talbot professor of municipal and sanitary engineering, University of Illinois; Alfred D. Flinn, director of Engineering Foundation and chairman of the Division of Engineering, National Research Council; George K. Burgess, chief of the Division of Metallurgy, U. S. Bureau of Standards; and Otto B. Blackwell, transmission development engineer, American Telephone and Telegraph Company, New York.

Mr. Talbot, who is a past-president of the civil engineers and chairman of their committee on research, discussed the society's research program, which has included such important subjects as working stresses for steel structures, flood-protection data, irrigation engineering, hydraulic phenomena, and impact in highway bridges. Mr. Flinn reviewed the development of the two organizations in which he is active, as previously named, stating that each of them is "an integral part of the organism of the founder societies, just as the Library is." Mr. Burgess reviewed the present status and probable future of steel as a structural material and outlined some of the work being carried on at the Bureau of Standards.

Subjects considered at the city planning session were parks and parkways, city planning and the engineer, zoning, and regional planning.

At an evening session on January 18 Julius H. Barnes, president of the U. S. Chamber of Commerce, presented an address on Transportation Keyed to Production, in which he emphasized the necessity for adequate transportation facilities for distribution of products.

LIBRARY NOTES AND BOOK REVIEWS

American Machinist Gear Book. By Charles H. Logue; revised by Reginald Trautschold. Third edition. McGraw-Hill Book Co., New York, 1922 Cloth, 6 × 9 in., 353 pp., illus., diagrams, tables, $3.

This book is intended to give practical data for cutting, molding, rolling and designing commercial types of gears, and to present this information by means of simple rules, diagrams and tables arranged for ready reference. This edition has been carefully revised and enlarged. Matter of little practical value has been omitted. The chief additions relate to spiral type and Williams "master form" bench gears, to the Williams system of internal gearing and rolled gearing. The last subject is here first presented in book form.

Annuaire du Bureau des Longitudes. 1923 By France: Bureau des Longitudes. Gauthier-Villars et Cie, Paris, 1922. Paper, 4 × 6 in., 860 pp., portrait, maps, tables, 6 fr. 5 c.

This convenient reference book has appeared annually for 128 years. The volume for 1923, like its predecessors, covers a wide field of statistical information, astronomical, physical, geographical and social. Five star maps are included, and an extensive review of the climate of France.

Cours Complet de Mathématiques Spéciales; Vol. 3, Méchanique. By J. Haag. Gauthier-Villars et Cie, Paris, 1922. Paper, 6 × 10 in., 188 pp. 12 fr.

In this volume on mechanics, Professor Haag lays emphasis on the experimental origin of that science, even though he proves that an entirely abstract exposition of it may be given, as of any other mathematical theory. His study begins with kinematics, from which topic he proceeds to dynamics and finally to statics, which is considered as a particular case of dynamics. Although primarily a work on theoretical mechanics, applied mechanics has not been neglected, but has been included by a large number of problems that occur in physics or in industry.

Dictionary of Applied Chemistry. Vol. 4. By Sir Edward Thorpe. Longmans, Green & Co., New York, 1922. Cloth, 6 × 9 in., 740 pp., $20.

This well-known work of reference has been thoroughly revised and brought down to date, the present volume including matter published as recently as 1922. Volume 4 includes many subjects of technical interest, such as the manufacture of matches, of nitric acid; the utilization of atmospheric nitrogen; the metallurgy of lead, magnesium, nickel, mercury, osmium and molybdenum; metallography; mercerizing; leather; naphthalene. Extensive articles on these and other topics, by well-known authorities, characterize the book.

The Dynamo, Its Theory, Design and Manufacture. Vol. 1. By C. C. Hawkins. Sixth edition. Isaac Pitman & Sons, New York, 1922. Cloth, 6 × 9 in., 615 pp., illus., diagrams. $6.

A standard British text of comprehensive character, covering both direct- and alternating-current generators. In this revision greater space is given to the treatment of the electromotive force of the dynamo by vectorial methods, the theory of armature winding has been reconsidered and expanded, and greater prominence is given to drum armatures. A section on the oscillation of a mechanical system, a discussion of the compressive stress on the mica plates in high-speed commutators, and the winding of shunt coils with two sizes of wire are among the new matters that have been added. The book has been largely rewritten and carefully revised.

Elementary Internal-Combustion Engines. By J. W. Kershaw. Second edition. Longmans, Green & Co, New York, 1922. Cloth, 5 × 7 in, 211 pp., diagrams. $1.75.

An elementary account of the construction and working of oil and gas engines and power-gas producers, intended as an introduction to more advanced books.

Internal-Combustion Engines. By J. Okill. Isaac Pitman & Sons, New York, 1922 (Pitman's Common commodities and industries). Cloth, 5 × 7 in., 126 pp, illus. $1.

A review of the development and construction of the various types of internal-combustion engines, written to show how gas and oil engines stand as competitors to steam for all power purposes, and to discuss some of the power requirements that are beyond the scope of the steam engine.

Introduction to Theoretical and Applied Colloid Chemistry. By Wolfgang Ostwald. Second American edition, translated from the eighth German edition by M. H. Fischer. John Wiley & Sons, New York, 1922. Cloth, 6 × 9 in., 266 pp., illus., diagrams, portrait. $2.50.

A revised and enlarged edition of the principal lectures delivered by the author during his American visit in 1913–1914. These lectures were intended for those with little or no knowledge of colloid chemistry and were intended as a general survey of the

subject, with particular emphasis upon its great possibilities of scientific and technical application.

Experimental Electrical Engineering and Manual for Electrical Testing. Vol. I. By Vladimir Karapetoff. Third edition. John Wiley & Sons, New York, 1922. Cloth, 6 × 9 in., 795 pp., illus., diagrams. $6.

This textbook on the testing of electrical machinery is based on the course of instruction given by the author at Cornell University, but the selection of material has been modified by comparison with the courses in other colleges, so that the book presents a composite picture of what is actually taught in the electrical laboratories in this country. This edition has been completely revised and reset. Volume 1 contains all elementary experiments and is sufficient for the needs of general students. Volume 2 contains advanced work needed by students of electrical engineering.

Jigs and Fixtures. By Fred H. Colvin and Lucian L. Haas. Second edition. McGraw-Hill Book Co., New York, 1922. Cloth, 6 × 9 in. 237 pp., illus., diagrams, tables. $2.50.

The authors endeavor to present the fundamental principles of design, arranged as nearly in the order of their application as possible, so that the tool designer can select such parts and methods as seem best suited to any problem. The new edition has been enlarged to include a greater variety of work and also to show a few boring bars and reamers.

Labor Turnover in Industry. By Paul Frederick Brissenden and Emil Frankel. Macmillan Co , New York, 1922. Cloth, 6 × 9 in., 215 pp., tables. $3.50.

The questions discussed in this work include the general extent of labor mobility; labor mobility in individual plants and in special groups within the work force, causes of turnover, seasonal influences, effects of length of service, responsibility for instability. The investigation is based on statistics collected for the United States Bureau of Labor Statistics, from over 260 establishments employing over 500,000 workers. The problem is treated primarily from the point of view of the individual establishment.

Machinery Foundations and Erection. By Terrell Croft. First edition McGraw-Hill Book Co., New York, 1923. Cloth, 6 × 8 in., 691 pp., illus., diagrams. $5.

Section 1 of this book considers the general requirements that foundations for machinery must meet. This statement of fundamentals is immediately followed by divisions treating of the design and properties of the different components of foundations, such as anchor bolts, anchor plates and anchors. Following these come instructions on the installation and reconstruction of foundations. The divisions in the next group give specific information on the design and construction of foundations for certain types of machinery, including steam engines and turbines, boilers, waterwheels, electrical machinery, hammers and planers. The concluding divisions explain methods for erecting machinery. The book is written for practical men, and avoids the use of higher mathematics. Little has been written previously on the subject.

Mechanical Engineering Detail Tables. By John P Ross. Isaac Pitman & Sons, New York, 1923. Cloth, 5 × 7 in., 197 pp., diagrams, tables. $2.25.

This compilation, by an experienced draftsman, is intended to supply machine designers with the proportions of a number of machine details that are common to all machines. The tables include dimensions for the usual sizes of studs, rivets, nuts, bolts, handles, ratchets, wrenches, links, joints, shafting, keys, keyways, bearings, hooks, chains, engine and pump details, condenser details, valves and cocks, pipes, flanges and fittings, ship's fittings and wire ropes. Follows English practice.

Oil Power. By Sydney H. North. Isaac Pitman & Sons, New York, 1922 (Pitman's Common Commodities and Industries). Cloth, 5 × 7 in., 122 pp., illus , tables. $1.

A concise, yet comprehensive account of the use of oil for power production, which covers the subject in a general manner, without attempting great detail on its many aspects. Intended for engineers, shipowners and users of fuel. Gives special attention to the economic ad antages of oil.

Practical Mechanics and Strength of Materials. By Charles W. Leigh. First edition. McGraw-Hill Book Co., New York, 1923. Cloth, 5 × 8 in., 293 pp., diagrams, tables. $2.25.

An elementary textbook presenting those principles of mechanics and strength of materials that are needed by the practical man. Intended for high schools and vocational schools.

Quantum Theory. By Fritz Reiche. E. P. Dutton & Co., New York, Cloth, 5 × 8 in., 183 pp. $2.50.

In this treatise the author has attempted to give in broad outline the most important features of the doctrine of quanta, its origin, its development and its ramifications. An appendix entitled Mathematical Notes and References provides a useful list of the important writings on the subject.

Die Statik des Eisenbaues. By W. L. Andrée. Second edition. R. Oldenbourg, Munich, Berlin, 1922. Paper, 6 × 10 in., 521 pp., diagrams, tables $3.

A practical handbook for the designer of steel structures, intended to give him a collection of the most useful methods for solving the problems of statics that arise in the design of ordinary structures. The book contains over one hundred examples, taken from practice, of steel buildings, shops, markets, craneways, hangars, shipways, conveyor frames, cooling towers, bridges, cableways, loading bridges, pontoon bridges, etc. In every case, the author has tried to present the most suitable method of calculation. An appendix presents, in concise form, the foundation and development of the most important method for statically indeterminate systems.

Treatise on the Principles and Practice of Dock Engineering. By Brysson Cunningham. Third edition. Charles Griffin & Co., London, 1922. Cloth, 6 × 9 in , 600 pp , illus , plates. $10.00.

Mr. Cunningham's treatise covers the subjects of dock design and construction; jetties, wharfs and piers; dock gates and caissons; sheds and warehouses; dock bridges and dock equipment. The book aims to be thorough, rather than extensive, in its treatment; and to investigate in detail rather than in general. This edition has been thoroughly revised and brought up to date by the inclusion of new material and illustrations.

Index to Volume 44 of Mechanical Engineering

THE Index to Volume 44 of Mechanical Engineering has recently been completed and is now available in printed form. Any member of The American Society of Mechanical Engineers or any other subscriber to the magazine may obtain a copy of this Index by sending a written request for it to the headquarters of the Society at 29 West 39th Street, New York, N. Y.

Acting Director of U. S. Standards Bureau

THE VACANCY caused by the resignation of Dr. S. W. Stratton as director of the U. S. Bureau of Standards has been filled temporarily by the appointment of Dr. Fay C. Brown as acting director. Dr. Brown has been assistant director since the War. He is a graduate of the University of Indiana and did graduate work at the Universities of Illinois and Chicago and at Princeton. He was instructor at the Universities of Illinois and Iowa previous to the War. In 1917 he entered the military service and was in charge of testing and ballistic work on airplane bombs.

New President of British Mining Engineers

THE INSTITUTION of Mining and Metallurgy, of England, which is international and comprises a large American membership, has selected Robert Gilman Brown as its president for 1923–1924. Mr. Brown is a graduate of Dartmouth and the Columbia School of Mines and was connected with various mining concerns in this country until 1907, when he went to England. He has since been associated, either as consulting engineer or director, with mining companies operating in Cornwall, North Wales, South America, Burma, and particularly in Russia. He has been a member of the council of the Institution for eleven years, and is the second American engineer to be its president, the first having been Hennen Jennings.

THE ENGINEERING INDEX

(Registered United States, Great Britain and Canada)

Exigencies of publication make it necessary to put the main body of The Engineering Index (p. 111-EI of the advertising section) into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.

AIRPLANES

Manless. The Army's Manless Airplane. Aerial Age, vol. 16, no. 2, Feb. 1923, p. 73. Results of experiments by Army Air Service to produce small airplane of 20-ft. span, with 60-hp. air-cooled engine, capable of carrying useful load of 250 lb., which would operate without pilot; equipped with Sperry automatic pilot.

AUTOMOBILE ENGINES

Motor-Truck. Type K-4 Continental Truck Engine Goes Into Production. Automotive Industries, vol. 48, no. 5, Feb. 1, 1923, pp. 231–232, 2 figs. Has detachable cylinder head and full-pressure lubrication; gives 35 hp. at 1300 r.p.m., at which speed it is intended to be governed; weight, 680 lb.

AUTOMOBILES

Bodies in Sections. Manufacturing and Shipping Costs Cut by Building Bodies in Sections, J. Edward Schipper. Automotive Industries, vol. 48, no. 5, Feb. 1, 1923. pp. 215–217, 7 figs. 30 broughams packed in same freight-car space as 14 under usual method; Oldsmobile plan provides for shipping in seven sections; bolted and screwed together in car factory.

BELTING

Leather. New Federal Specifications for Leather Belting, Louis W. Arny. Indus. Management (N. Y.), vol. 65, no. 2, Feb. 1923, p. 92. Discusses new specifications adopted by U. S. Government.

BOILER FURNACES

CO_2 Distribution. Stratification of Gases Within a Boiler Furnace, W. C. Stronk. Power, vol. 57, no. 5, Jan. 30, 1923, pp. 166–168, 6 figs. Method of taking combustion-chamber gas samples; four sets of analyses show air distribution in furnaces; operation relation of CO_2 and O_2 shown; method suggested to improve combustion efficiency.

CARBURETORS

Venturi Diameters. Determining Correct Carburetor Size, W. H. Weber. Automotive Industries, vol. 48, no. 5, Feb. 1, 1923, pp. 220–221. Practical method for calculating cross-section of venturi tube necessary for carburetor to permit quick acceleration from minimum car speed in high gear.

DIE CASTING

Dies for. Dies for Die-Castings, A. G. Carman. Machy. (N. Y.), vol. 29, no. 6, Feb. 1923, pp. 430–432, 4 figs. Specific examples of design and construction of dies for making die castings of more intricate types.

Process and Equipment. Die Casting Process and Equipment, John W. Harriman. Am. Mach., vol. 58, no. 4, Jan. 25, 1923, pp. 137–141, 10 figs. Construction and operation of die; what to allow for shrinkage; methods of forcing molten metal into die are described.

DISKS

Rotating, Stresses in. Rotating Discs of Conical Profile. Engineering, vol. 115, nos. 2975 and 2978, Jan. 5 and 26, 1923, pp. 1–3 and 115–116, 4 figs. Determination of stresses due to centrifugal forces acting alone, application of load of, say, 1 lb. per in. run applied along knife edge forming periphery, and infinitely great pressure applied to the interior of an infinitely small hole drilled through the disk at its center.

GAS ENGINES

Steel Works. Large Gas Engines Installed in Steel Plants, C. G. Sprado. Blast Furnace & Steel Plant, vol. 11, no. 1, Jan. 1923, pp. 123–125, 5 figs. Comparison of B.t.u. recoveries by gas engines versus steam units; marked advance in valve-gear construction results in unexpected economy and capacity in new 3500-kw. machines.

GEAR CUTTING

Helical Gears. Methods of Generating Helical Gears, Franklin D. Jones. Machy. (N. Y.), vol. 29, no. 6, Feb. 1923, pp. 445–450, 15 figs. Methods of cutting teeth of helical gears on hobbing machines and gear shapers.

Sykes Generators. Large Sykes Gear Generators. Engineering, vol. 115, no. 2977, Jan. 19, 1923, p. 69, 11 figs. on p. 78 and supp. plate. Details of machines of two models, both capable of cutting wheels up to 15 ft. in diameter.

Tangent Rack Gears. Hobbing Tangent Rack Gears. Engineering, vol. 115, no. 2978, Jan. 26, 1923, pp. 106–107, 10 figs. Describes system of generating gearing by means of conical hob devised by H. E. Taylor of Hotchkiss et Cie., Coventry, England.

GEARS

Spiral Bevel. The Manufacture of Spiral Bevel Gears. Engineering, vol. 115, no. 2976, Jan. 12, 1923, pp. 32–36,13 figs., partly on p. 46. Describes works and methods used by E. N. V. Motors, Ltd., London.

INDICATORS

Steam-Engine. High-Speed Engine Indicators. Engineering, vol. 115, no. 2978, Jan. 26, 1923, pp. 119–126, 34 figs. Four papers read before Instn. Mech. Engrs. as follows: The Problems of the Engine Indicator, Loughnan Pendred; A New Form of Optical Indicator, F. W. Burstall; Micro-Indicator for High-Speed Engines, W. G. Collins; R. A. E. Electrical Indicator for High-Speed Internal-Combustion Engines, and Gauge for Maximum Pressures, Harry Wood.

Indicators for High-Speed Engines. Engineering, vol. 115, no. 2976, Jan. 12, 1923, pp. 31–32. Discusses optical indicators, including Hopkinson, Watson and Burstall in England, and Midgley, in America.

INDUSTRIAL MANAGEMENT

Engineering Department. The Successful Operation of an Engineering Department, W. E. Irish. Indus. Management (N. Y.), vol. 65, no. 2, Feb. 1923, pp. 93–97. Consideration of labor problems from engineer's viewpoint—men as "cogs," foremen as "bearings," etc. Shows how method has worked out in practice.

Lot-Quantity Determination. How to Determine Quantities for Lot Manufacture, Kenneth W. Stillman. Indus. Management (N. Y.), vol. 65, no. 2, Feb. 1923, pp. 84–86, 2 figs. Finding most economical lot quantity by graphs.

Production Methods. Undetected Faults in Production Processes, A. Whitehead. Engineer, vol. 135, no. 3499, Jan. 19, 1923, pp. 72–73, 1 fig. Points out influence of defects in workmanship or processes which ordinary methods of inspection commonly neglect.

IRON CASTINGS

Electric-Furnace. Gray Iron Castings from Electric Furnace, Larry J. Barton. Iron Age, vol. 111, no. 4, Jan. 25, 1923, pp. 269–273, 8 figs. Possibility of their commercial production; acid and basic practice compared; role of heat treatment.

JIGS

Design. Jigs and Tools, J. Moore. Engineering, vol. 115, no. 2976, Jan. 12, 1923, pp. 55–59, 13 figs. Considerations and principles of design. (Abstract.) Paper read before Instn. Production Engrs.

LOCOMOTIVE BOILERS

Washing-Out and Refilling Plant. Locomotive Washing-Out Plant for the Italian State Railways. Engineering, vol. 115, no. 2976, Jan. 12, 1923, pp. 42–44, 8 figs. Details of washing-out and refilling plant, underlying idea of which is to recover heat stored in boilers of locomotives returning to sheds, and use it in boilers of locomotives starting for day's work.

LOCOMOTIVES

Repairing. How Locomotives Are Repaired on Ford's Railway, Fred H. Colvin. Am. Mach., vol. 58, no. 4, Jan. 25, 1923, pp. 133–136, 14 figs. Describes repair shop at River Rouge and methods employed.

MONEL METAL

Forging. Considerations in the Forging of Monel Metal. Forging & Heat Treating, vol. 8, no. 12, Dec. 1922, pp. 542–545, 3 figs. Importance of heating in a reducing atmosphere or muffle furnace emphasized; correct temperature for forging; physical and chemical properties of monel metal.

MOTOR TRUCKS

Performance Tests. Production Tests of Loaded Chassis at the G. M. C. Truck Plant. Automotive Industries, vol. 48, no. 5, Feb. 1, 1923, pp. 224–226, 7 figs. To obtain more comprehensive and accurate data on truck chassis performance than would be possible through road tests, Gen. Motors Truck Co. has provided test room through which all completed chassis must pass.

OIL ENGINES

European. European Oil Engines, Edwin Lundgren. Power, vol. 57, no. 5, Jan. 30, 1923, pp. 171–172, 3 figs. Discussion of correct air-oil mixing; the Deutz engine; new Hesselmann solid-injection engine.

OPEN-HEARTH FURNACES

Developments. Developments in the Open Hearth, Herbert F. Miller, Jr. Blast Furnace & Steel Plant, vol. 11, no. 1, Jan. 1923, pp. 48–51, 3 figs. Gas-producer development and possibilities of coke-oven gas; furnace valves, door frames and ports; suggestion of evolution of open-hearth similar to modern blast furnace.

PRESSES

Forging, Hydraulic. The Practical Side of the Design of Hydraulic Forging Presses, W. R. Ward. Forging & Heat Treating, vol. 8, no. 12, Dec. 1922, pp. 553–557, 5 figs. Detailed discussion of design; calculations and materials; application and limitations of various presses.

REFRIGERATING PLANTS

Performance Scale. A Performance Scale for Ammonia Refrigerating Plants, T. M. Gunn. Power, vol. 57, no. 6, Feb. 6, 1923, pp. 211–214, 1 fig. Discusses performance and gives scale by which operating results may be compared with ideal ones for any pressure range.

ROLLING MILLS

Foreign Practice. Foreign Blooming Mill Practice, C. Kiesselbach. Blast Furnace & Steel Plant, vol. 11, no. 1, Jan. 1923, pp. 83–85, 7 figs. Series of production studies to determine proper number of passes; cooling due to roll contact rather than time intervals; power requirements at various reductions does not vary greatly. Translated from Stahl u. Eisen, Jan. 15, 1920.

STEAM ENGINES

Extraction-Type. Governing Devices of British Steam-Extraction Engines. Power, vol. 57, no. 5, Jan. 30, 1923, pp. 173–174, 2 figs. Methods whereby satisfactory regulation is obtained on British engines.

STEAM GENERATORS

Electric. Laurentide Electric Steam Generators Largest Yet Installed, W. P. Muit. Power, vol. 57, no. 6, Feb. 6, 1923, pp. 208–210, 4 figs. Two units, each consisting of three sections, connected on 6600-volt 3-phase circuit; each generator has normal capacity of 25,000 kw. and has absorbed 35,000 kw. and produced 50 tons of steam per hr.

STEAM POWER PLANTS

Compound-Engine. Plant of Brunswick-Balke-Collender Co., Muskegon, Michigan. Power, vol. 57, no. 6, Feb. 6, 1923, pp. 200–205, 7 figs. Compound-engine non-condensing plant in which exhaust steam is used for process work, dry kilns and heating; water raised by air lift; special coal and ash handling.

STEAM TURBINES

Axial-Flow Ljungström. Axial-Flow Ljungström Turbine. Power, vol. 57, no. 6, Feb. 6, 1923, pp. 229–230, 3 figs. Rotor is built up of a number of disks and annular rings; combined impulse-and-reaction-type unit forms part of 70-ton passenger locomotive that has seen regular service since March 1922; 1800 hp. developed at 9200 r.p.m. Translated from Zeit. des Vereines deutscher Ingenieure, Nov. 18, 1922.

Manufacture. Making Engineering Product on a Factory Basis, L. S. Love. Iron Age, vol. 111, no. 5, Feb. 1, 1923, pp. 333–336, 6 figs. Building turbines with consideration to variations of conditions of use by simplification and standardization.

STEEL

Fatigue Testing. Determination of the Fatigue-Resisting Capacity of Steel Under Alternating Stress, T. Robson. Engineering, vol. 115, no. 2977, Jan. 19, 1923, pp. 67–69, 4 figs. Describes arrangement adopted by Vincent Raven in testing department of North-Eastern Ry., machine used being Wohler cantilever type.

STEEL CASTINGS

Centrifugal Process. Special Products Made Centrifugally, George F. Tegan. Iron Age, vol. 111, no. 5, Feb. 1, 1923, pp. 337–338, 3 figs. Steel disk ingots for tires, wheels and other shapes produced by McConway process; billets and wire from such ingots.

Heat Treatment. Heat Treatment of Steel Castings, F. C. Langenberg. Iron Age, vol. 111, no. 6, Feb. 8, 1923, pp. 397–400, 2 figs. Methods of improving physical properties and bearing on specifications; effect on impact values of electric and open-hearth steel.

Heat Treatment of Steel Castings, H. C. Ihsen. Blast Furnace & Steel Plant, vol. 11, no. 1, Jan. 1923, pp. 95–99, 17 figs. Characteristics of steel castings in raw and thermally treated condition; consideration of correct treatment with relation to size and composition of casting.

STEEL MANUFACTURE

Calorific Value of Elements Used. Calorific Value of Steel-Making Elements, Henry D. Hibbard. Iron Age, vol. 111, nos. 2, 3 and 5, Jan. 11, 18 and Feb. 1, 1922, pp. 143–144, 211–213 and 347–349. Jan. 11: Chemistry of fusion or behavior and influence of each element on metallurgy of iron. Jan. 18: Role of silicon in bessemer and open-hearth furnace; proper use of aluminum; magnesium as deoxidizer. Feb. 1: Behavior of phosphorus, manganese chromium and other metals in steel processes; peculiarities of sulphur.

TERMINALS, LOCOMOTIVE

Design. An Innovation in Locomotive Terminal Design. Ry. Age, vol. 74, no. 4, Jan. 27, 1923, pp. 281–284, 3 figs. Rectangular or circular engine houses with inside cinder pits designed for promptly turning power. Designed by Nat. Boiler Washing Co., Chicago.

TERMINALS, RAILWAY

Chicago. Chicago Gets a New Passenger Terminal Plan. Ry. Age, vol. 74, no. 4, Jan. 27, 1923, pp. 263–267, 7 figs. Plans for new project by Chicago & West. Indiana, comprising study for new facilities on Dearborn Station site.

Mechanical Engineering

The Monthly Journal Published by

The American Society of Mechanical Engineers

Publication Office, 207 Church Street, Easton, Pa. Editorial and Advertising Departments at the Headquarters of the Society, 29 West Thirty-ninth Street, New York

Volume 45 April, 1923 Number 4

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ADVERTISING

Price 50 Cents a Copy, $4.00 a year: to Members and Affiliates, 40 cents a Copy, $3.00 a Year. Postage to Canada, 75 Cents Additional; to Foreign Countries, $1.50 Additional. Changes of address should be sent to the Society Headquarters.

Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879.
Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921.

Contributors and Contributions

Large Machine Tools; Design and Construction

George H. Benzon, Jr., outlines in this issue the general character of the work of design and construction of large machine tools. This paper was one of a group of papers on machine tools presented at a recent joint meeting of the Philadelphia Local Section and Machine-Shop Division of the A.S.M.E. the Engineers' Club of Philadelphia and the Philadelphia Section of the A.I.E.E.

Mr. Benzon has been associated with Wm. Sellers & Co., Inc., Philadelphia, since 1898 when he served his drafting-room apprenticeship with that concern. In 1904 he was put in charge of planer design and construction, and four years later became chief draftsman. Since 1919 he has held the position of engineer.

Efficiency of Scotch Marine Boiler

In his paper dealing with this subject, C. J. Jefferson shows what has been effected by careful operation and provides a definite target of boiler efficiency at which marine engineers may aim with profit. Mr. Jefferson is a 1910 graduate of Cornell University. For seven years he was associated with the American Ice Co. as testing and mechanical engineer. During the War he served as a lieutenant in the U. S. Navy. Upon his discharge he took charge of the Boiler Unit, Technical Section of the U. S. Shipping Board. At present Mr. Jefferson is head of the Fuel Conservation Section of the U. S. Shipping Board.

Effect of Pulsations on Flow of Gases

This paper, by Prof. Horace Judd and D. B. Pheley, discusses work undertaken under the joint direction of the engineering Experiment Station of Ohio State University and the A.S.M.E. Research Sub-Committee on Fluid Meters. Professor Judd was graduated from Ohio State University in 1897 with the degree of M.E. and then served for two years as an instructor in the mechanical engineering laboratory, receiving his M.S. at the end of that period. For three years he held a similar position in Pratt Institute, Brooklyn, and then returned to Ohio State University to serve as assistant professor of experimental engineering until 1910 and as associate professor until 1920, when he was appointed professor of hydraulic engineering.

Mr. Pheley is at present junior engineer in the U. S. Coast and Geodetic Survey. He was graduated from Ohio State University in 1921 as a civil engineer and during that summer served as assistant to Professor Judd in the study of and experimental work in the problem of pulsating flow.

Engineering Aspects of the Design of Musical Instruments

The specific problems presented in the manufacture of pianofortes are considered by William Braid White, who shows that vast improvements would be achieved if the principles of mechanical engineering were more generally adopted as the foundation of such manufacture. Mr. White, an Englishman by birth, was educated at St. Paul's School and King's College, London. He came to the United States in 1896 and became interested in piano making. Since 1904 he has been technical editor of the *Music Trade Review*, New York; he is also associate editor of the *Talking Machine World*, New York.

Airship for Long-Haul Heavy-Traffic Service

The factors upon which the value of an airship as a carrier depends form the subject of this paper. Ralph H. Upson, the author, is chief engineer of the Aircraft Development Corporation of Detroit. He was graduated from Stevens Institute of Technology in 1910 with the degree of M.E. and entered the aeronautic department of the Goodyear Tire and Rubber Co., Akron, Ohio. He designed and built his first complete balloon in 1912, and in 1913 won the national and international balloon races. The Wingfoot Lake Flying School was started by Mr. Upson in 1917. He won national balloon races in 1919 and 1921, served on the Navy Department Commission in Europe, 1918–1919, and studied European methods in 1920. From 1915 to 1920 he was chief engineer of the Goodyear aeronautical department.

Hydraulic-Transmission Variable-Speed Drive

The progress that has been made in applying "hydraulic transmission" variable-speed drive to machine tools and ordinary manufacturing processes is reported in this issue by Walter Ferris. Mr. Ferris was graduated from Lehigh University as a mechanical engineer, class of '95. Until 1900 he was employed by the Pencoyd Iron Works in the master mechanic's office, and by the Laflin & Rand Powder Co. in charge of the design and erection of powder mills. From 1902 to 1921 he served the Bucyrus Co., South Milwaukee, Wis., as draftsman, chief engineer and consulting engineer, consecutively. The Oilgear Co., of which Mr. Ferris is vice-president, was organized in 1920.

Safety Engineering in Compression of Gases

This paper outlines a few of the chief hazards that are associated with the compression of some of the gases in common use in industry. Its author, A. D. Risteen, was graduated from Worcester Polytechnic Institute in 1885 with the degree of B.S. He received his Ph.D. from Yale in 1903. For twenty-three years he was associated with the Hartford Steam Boiler Inspection & Insurance Co. For the last ten years he has been in the engineering division of the Travelers Insurance Co., and is now director of technical research and safety publication work for that concern and the Travelers Indemnity Co.

A.S.M.E. Pacific Coast Regional Meeting

Los Angeles, April 16-18, 1923

For Details of Program and Interesting Excursions, See Current Numbers of A.S.M.E. NEWS

A.S.M.E. Spring Meeting, Montreal, May 28-31, 1923

MECHANICAL ENGINEERING

Volume 45 | April, 1923 | No. 4

Design and Construction of Large Machine Tools

Limitations Imposed on Design by Materials and Available Shop Equipment—Problems Involved in the Design and Construction of Large Boring Mills and Planers

By GEO. H. BENZON, JR.,[1] PHILADELPHIA, PA.

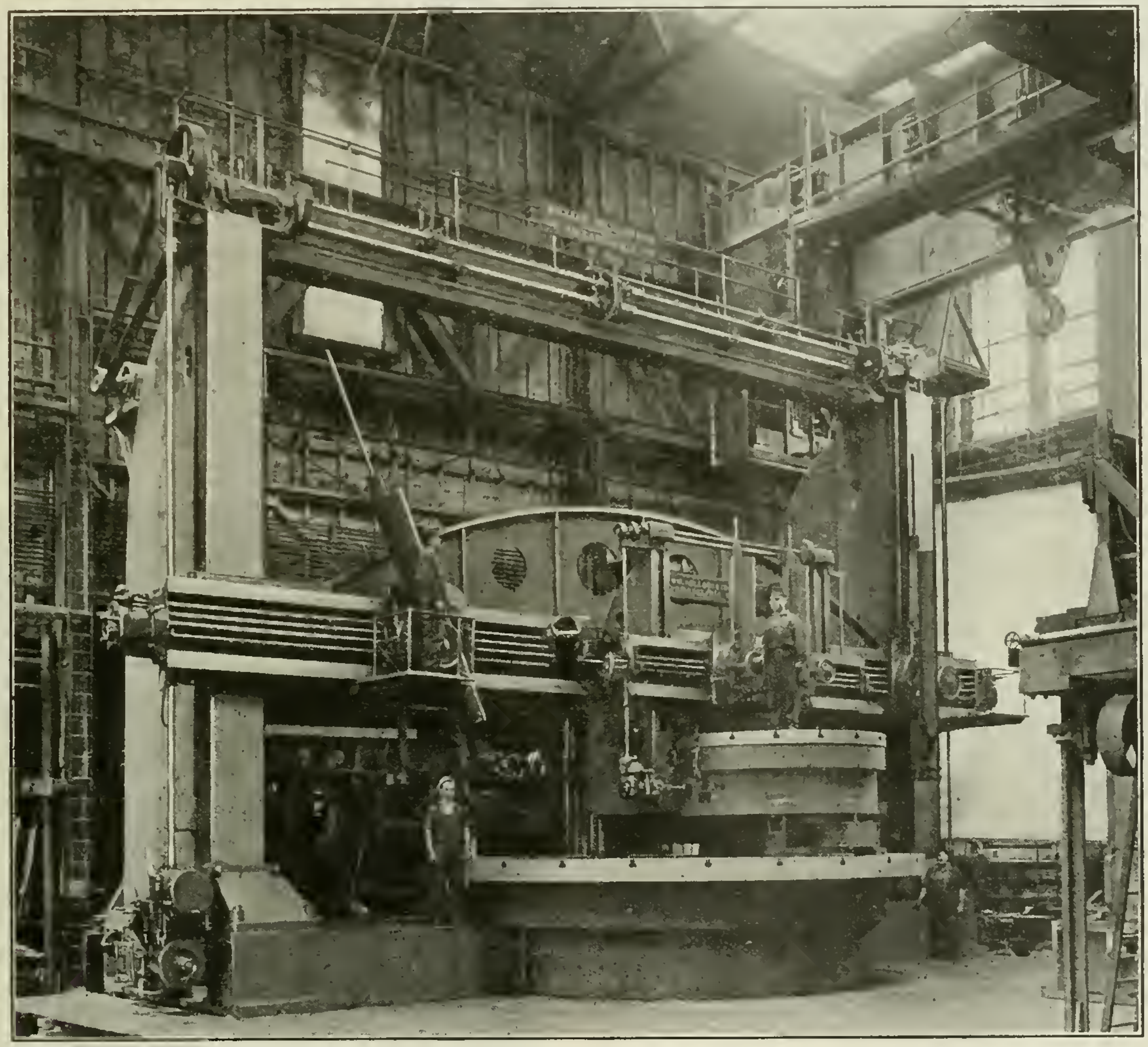

Fig. 1 Large Boring and Turning Mill
(Swing between uprights, 35 ft.; clearance between work table and underside of tool head, 18 ft.; total weight, 429,200 lb. Note small mill set on work table of large mill; swing between uprights, 100 in.)

IT HAS BEEN difficult in preparing this paper to sort out from the mass of every-day facts those points which might be of interest in a general discussion such as seems to be indicated by the title selected. The subject as generally understood is a very broad one. In fact, it covers two somewhat different types of machines commonly classed under the general title. There are machines which are used for accurate cutting and finishing; these belong distinctly in the machine-tool class. There are also those which are used for metal working other than finishing. While these may be, and are, often considered to be in this class, there is no sharp line between them and the machines used for metal working which are grouped under other machine divisions. The first-mentioned class, however, will be the one made the subject of this discussion.

The shops building hydroelectric machinery, marine engines, blowing engines, and rolling-mill machinery have been the main sources of demand for large machine tools. Ordnance and battleship development during the late war created demands that bade fair to swamp the large machine-tool builders, but these subsided and dropped out entirely after the cessation of hostilities. Large marine Diesel engines, if commercially developed in this country, will probably widen further the market for large machine tools.

It is obvious and natural that the demand for large tools di-

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Presented at a joint meeting of the Philadelphia Local Section and the Machine Shop Division of The American Society of Mechanical Engineers, the Engineers' Club of Philadelphia, and the Philadelphia Section of the American Institute of Electrical Engineers, Philadelphia, February 27, 1923.

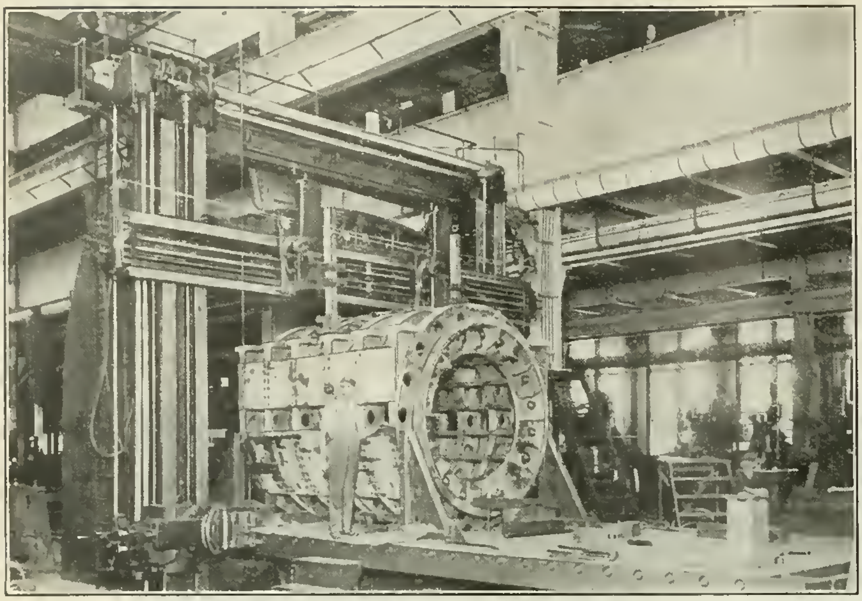

Fig. 2 Large Planing Machine

(Length of table, 38 ft. 6 in.; clearance between housings, 16 ft. 2 in.; distance from table to underside of crossrail, 13 ft. 4 in.; overall length of bed, 65 ft. 8 in.; total weight, 412,340 lb.)

minishes as the sizes of the tools increase. Developments of large mechanical and electrical projects of continually increasing size must include consideration of the means of production, and involve in many cases installations of large machine tools to accomplish the ends desired. The development of one such project frequently raises the general requirements in the particular industry to which it belongs and incites competing development. This may account in part for the spasmodic markets for the different lines of large machine tools. The requirement for these tools is very irregular. Some lines lie dormant for a long time, during which others are very active, and then the active ones drop out entirely for a period and others take their place. There are also times when the saturation point is temporarily reached, during which the whole market is dead.

From the foregoing it can readily be understood that large machine tools cannot be constructed or handled as a continuous manufacturing process. Consideration of this fact affects all branches of the industry from the design to the final inspection. The market has been so irregular as to make it seem inadvisable or uneconomical to equip and maintain establishments for the sole purpose of building such tools.

Machinery for building in the most efficient way the ever-increasing sizes of tools the market demands, would involve an investment far in excess of that which would predicate an equitable return. The machine-tool builder therefore in many instances has to use average large-shop equipment to produce tools of a larger size than any he has in his establishment. This condition requires considerable attention from the designer, who must plan the large units of the machine so that they may be handled by existing equipment and at the same time not suffer in their value as a part of the big machine tool.

Limitations Imposed on the Designer

Large patterns are bulky in storage and expensive in maintenance—to such an extent that in many cases the designer must try to adapt them to a variety of uses. It frequently pays to make a mold from a larger pattern and to stop it off with cores, rather than make a new pattern for the job. The time required to make new large patterns for a machine might affect delivery dates seriously and cause the loss of sales. The designer must bear all of this in mind, and also consider the feasibility and desirability of compromise in shaping the large units.

Another factor entering into the design and construction is the limiting sizes of parts that can be conveniently shipped. Bridge and tunnel clearances on the railroads limit the dimensions of parts that can be shipped as a unit. Machine tools must be made so that after having been assembled, tested, and corrected where necessary to an accuracy seldom matched in other mechanisms, they may be taken down, shipped, reassembled, and reproduced after these operations the same degree of accuracy as when under test.

The quality of machine tools for finishing is dependent on sound design backed up by expert foundry and machine work; and all of these factors must rest on the foundation of experience—not only that of the individual but that which lies in the records of an establishment. The grade of mechanic required in building these big tools is much higher than the average, the valuable men being those who have had a number of years of experience in this class of work. Detailed planning and instruction can rarely be applied in such work, and therefore the individual experience of the men, as well as of the foremen, has an appreciable effect on the character of work produced.

In the drafting room, as has been noted, there must be a thorough knowledge of shop conditions, shipping conditions, and of the difficulties encountered in previous experience in building the big machines. In the pattern shop and foundry there must be knowledge of the action of the molten metal in cooling, which will enable the patternmaker and the foundryman to gage with some degree of certainty the eccentricities of the metal in large castings so that those delivered to the machine shop will be sound, the bearing surfaces will show a good close-grained material, free from sand or casting defects, and the finished surfaces will have such hardness as will produce good wearing qualities and at the same time will not be too hard to machine satisfactorily without undue trouble with the cutting tools.

A large casting must be designed so that as far as possible the various sections will balance each other in cooling. Lack of balance in a long casting, for instance, if not properly compensated, will cause it to distort in cooling, often to such an extent that the amount of finish allowed in the pattern shop is of no use. There are some cases, however, where it is necessary to use unbalanced sections. In these cases experience teaches how much the mold should be distorted to offset the natural tendency of the casting. Big castings for machine tools require the handling of large quantities of molten

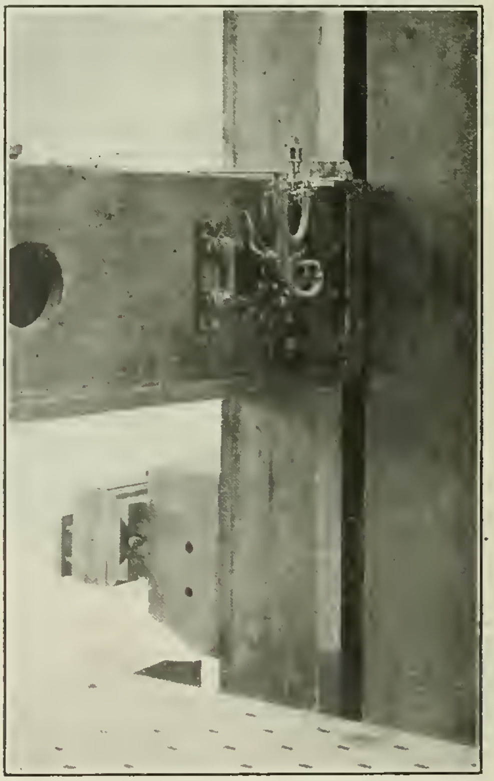

Fig. 3 Pneumatic Device for Clamping Planer Crossrail

metal in the very short time that can be allowed for pouring even the largest of castings. Interrupted flow of metal in pouring a large casting may, in fact will, if it occurs, detract from the value of the casting.

In order to produce a good close-grained material on the wearing surfaces of the machine, it has been found desirable and practical, using a high-silicon iron, to cool these surfaces quickly by casting them against chill blocks. The metal produced in this way is not what is known commercially as chilled iron. It is easily machined and not extremely brittle. While it is common knowledge that this method is desirable and practical, some years of experience as to size of chills and analysis of metal are essential in the making of large castings in order that satisfactory and consistent results may be obtained.

In the machine shop the castings must be properly handled to produce accuracy. All castings as they come from the foundry contain a great number of internal stresses. When some of these stresses are released in machining, others that they have been balancing are also released and produce distortion. It is therefore necessary that these large castings should be rough-machined in the proper sequence of operations and that enough time between be given for the stresses to work themselves out before final conditioning.

One of the disturbing factors in the construction of large machine tools is the variation in temperature between night and day and between floor temperatures and temperatures which exist at a height of, say, 25 ft. above the floor. For instance, in testing the alignment of the housings or uprights on large machine tools, variation in temperature will cause uprights to move from one side of a plumb line to the other in comparatively short time. Due allowance for variation in temperature, timing of the tests and inspection, during the course of erection, to fall under proper conditions, are very necessary in building these machines, particularly as such an upright must be plumb to within very close to a thousandth of an inch in its whole length.

The main bearings on large machine tools must be accurately fitted. To do this conveniently, where possible the bearings are capped and bushed and each bearing scraped to fit its individual shaft. The shaft bearings are ground. In fitting the shafts to the bearings on large machine tools, shoulders are turned on the shafts to suit. Measurements from the stands and housings after they are set up and bolted to place, are transferred to the shafts with proper allowances for running clearance. A properly designed bearing, if improperly fitted during erection, may in a very short time of running develop such trouble that the design of the bearing may be questioned and throw discredit on the machine performance.

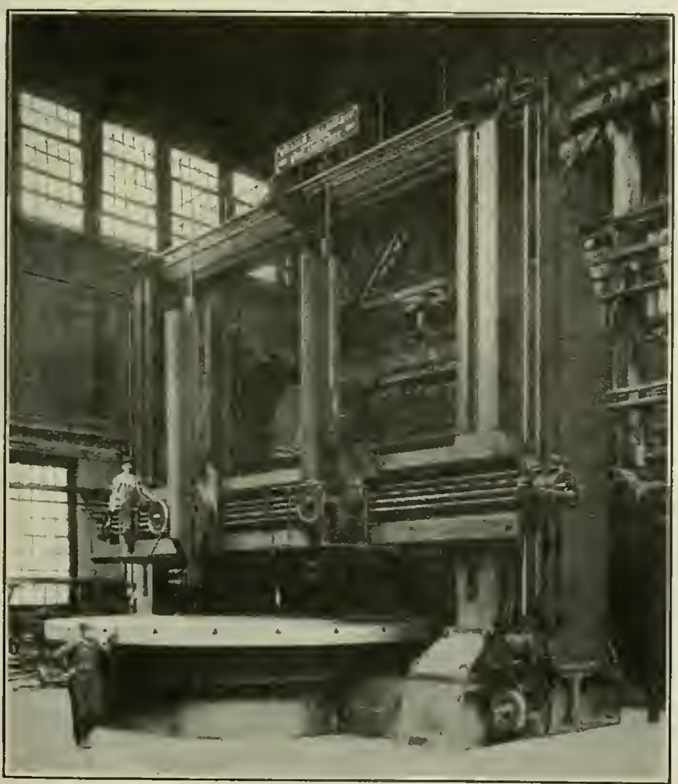

Fig. 4 25-Ft. Boring and Turning Mill with 10-Ft. Stroke of Tool

(The crossrail here is so deep vertically to meet requirements that the reinforcing arch girder is omitted satisfactorily. Total weight of machine, 373,130 lb.)

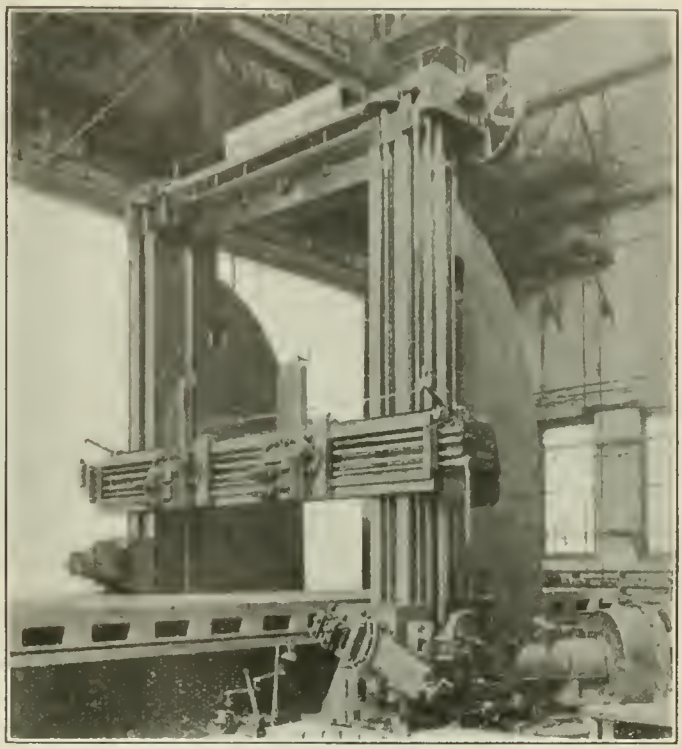

Fig. 5 12-Ft. Planing Machine

(As in the mill of Fig. 4, the crossrail is so deep vertically that a reinforcing arch girder is not needed.)

All of the main bearings in high-grade machine tools are bushed in order that (1) the best possible kind of metal may be provided for the bearing surface, and so that (2) in case of accidental cutting or scarring or wearing in service the bearing may be renewed by replacing an old bushing with a new one. In order that replacement may be properly effected the bushings are first bored and then turned on a mandrel so that concentricity of their inner and outer surfaces may result. This insures that a replaced bushing will restore correct alignment. The practice of boring bushings after they have been fastened in the stand is bad, and not tolerated by reputable builders.

Illustrations of Problems Confronting the Designer of Large Machine Tools

A detailed discussion of design and construction as applied to any one tool, to be complete, would take up more space than is available for all of this paper. However, one or two specific cases may be taken to illustrate some of the outstanding points.

Fig. 1 will give an idea of the proportions of a large boring and turning mill. To appreciate the size, comparison may be made with the medium-sized boring mill set on the work table of the large mill. The small mill shown swings 100 in. between the uprights or housings; the large mill swings 35 ft. and has a maximum clearance between the work table and the underside of tool heads of 18 ft. The rams at whose lower ends the cutting tools are carried have a stroke of 7 ft. The weights of some of the large castings are as follows: bed, 98,000 lb.; table, 73,000 lb.; crosshead bar, 66,000 lb.; total weight of machine, 429,200 lb.

The main problems confronting the designer in this instance were that the machine was to carry on the table work weighing up to 75 tons, bore a true hole 7 ft. long, and face and turn accurately. The accuracy required in the bore will probably not permit over 0.002 in. variation in round or in parallel in the length of 7 ft. To obtain the requisite accuracy the guides on the crossrail on which the tool heads move must be very close to a perfect parallel to the annular bearing surface on top of the bed. Obviously the tendency

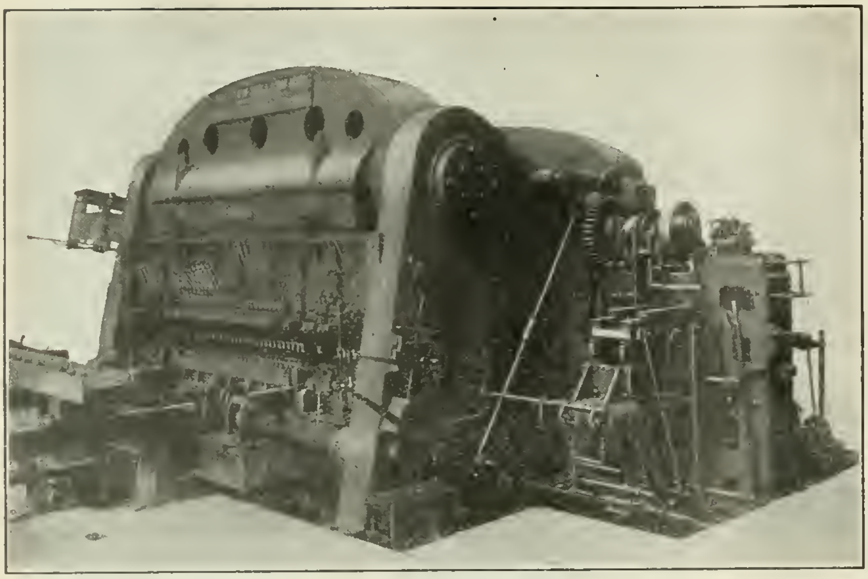

Fig. 6 Multiple Punching Machine, Operated Automatically from a Punched Paper Templet

(Used for duplicating layouts and very accurate in spacing. One of these machines has punched 59,600 holes in 9 hours. It may be broadly classed as a large machine tool.)

of a beam suspended on screws 36 ft. from center to center is to deflect somewhat, due to its own weight and the weight of the tool heads. To remove the sag in the crossrail, a separate casting in the form of an arched girder is bolted to the top of the crosshead bar. The arched girder is mounted between abutments at the two ends of the crossrail, in between the uprights and in a vertical plane as near to the front edge of the crossrail as saddle clearances permit.

Rigid Support for Cutting Tool

Another problem confronting the designer is that of supporting the cutting tool in a sufficiently rigid manner to take reasonably heavy boring cuts when the tool is extended, say, 7 ft. to 10 ft. below the bearing. This puts a bending as well as a twisting strain upon the tool bar, and a twisting and bending strain upon the crossrail. To resist these forces in the crossrail, the rail is made of a box construction. In the machine shown in Fig. 1 this box is a continuous section the full distance between the two uprights and is clamped at the back edge of this extended section to the uprights, at both sides. It is much easier to design a sufficiently rigid crossrail along these lines than in the case where the curved-back crossrail is used, in which the box section reinforcing the front of the rail starts from nothing just inside of the uprights and swells to its maximum dimension, horizontally, in the middle of the machine. With this latter construction the entire torsional strain is transferred to each end of the rail through the comparatively light section, while with the extended back the strain on the light section of rail which passes in front of the uprights is relieved considerably by the clamps securely holding the back edge of the crossrail to the uprights.

Fig. 2 shows a large planing machine erected in the shops of one of the large electrical manufacturing companies. A conception of the proportions of this machine can be formed by comparison with its surroundings and with the height of the workman standing on the table. It is made with a table to plane work 36 ft. long. The overall length of the bed is 65 ft. 8 in. The clearance between the housings is 16 ft. 2 in. and the distance from the table to the underside of the crossrail is 13 ft. 4 in. These figures fix the limits for the size of the work that can be handled on it. The bed weighs 123,400 lb. and the table (38 ft. 6 in. long) 151,000 lb., the total weight of the machine being 412,340 lb.

On a machine of this type the outstanding considerations are as follows: It must be so constructed that it will produce flat and parallel surfaces throughout its complete working range. The parallel accuracy is of course controlled to a great extent by the foundations upon which the machine is installed. Settling of foundations can very easily throw a long bed out of line to an extent that will affect this requirement. Where accurate work is required from a planer, the bed should be tested, for level and straight, at short periods, for some time after installation and thereafter at such periods as may be indicated by the character of the output of the machine. In the builder's shop, however, the machine must be set up so that it will plane flat and parallel within extreme limits of a few thousandths of an inch.

The same problem confronts the designer in this case as in that of the boring mill, namely, the design and construction of the rail on which the planing toolholders are carried. As the planers so far built have not reached the width between the uprights required on boring mills, it has not been necessary to make the crossrails of as heavy a section as on the boring mills; but the same considerations, on a reduced scale, indicate the desirability of the use of the arched girder to eliminate the initial deflection of the rail.

Planer Reciprocating Mechanism

Another feature of great importance is the question of adequate mechanism whereby the heavy table, and heavy work carried on the table, may be reciprocated at desirable speeds. The planing machine cuts in one direction. The two-direction-cutting planer came into and passed out of existence some years ago. The return stroke of the platen and work is therefore lost time, and must be reduced to the smallest possible amount in efficient production. The time required at each end of the stroke during which the planer must be slowed down, stopped, and reversed is another important item in production. A planer of this size can conceivably be used on a job requiring a stroke of 2 ft. in which the table loading is very high, say, 90 to 100 tons. Imagine the problem of reciprocating this heavy load, in addition to that of the table, backward and forward, cutting on one stroke and coming back to the cutting position on the other. The shock upon the mechanism and upon the fastenings holding the work to the table is obviously one that must be handled carefully. Up to the present time the table-driving mechanism of a planer has assumed two distinct forms. The one more commonly

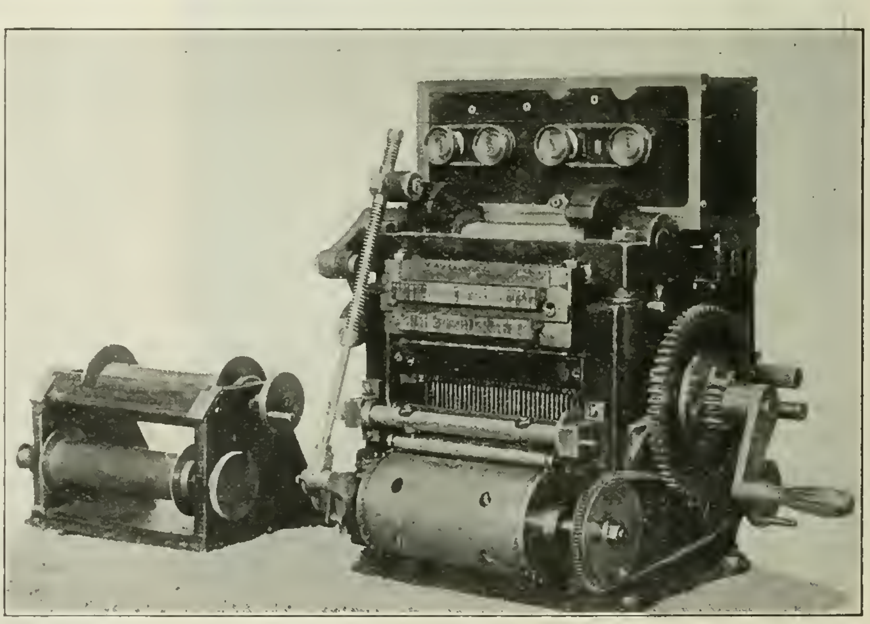

Fig. 7 Mechanism for Punching Paper Templates Used in Automatic Punching Machine Shown in Fig. 6. The Punched Template is Checked on the Rolls Shown at the Left

used is the obvious one and therefore the oldest, wherein the driving mechanism consists of a train of spur gears, reducing the speed from the power means to the proper speed of the work table or platen. These gears are sometimes modified to herringbone types. The power is delivered in all cases of recognized design through a rack bolted or clamped to the underside of the platen. The other type of drive, a recognized form for more than fifty years, is that known to the trade as the "Sellers" drive. The pinion which engages the rack is a helical pinion, commonly called "spiral pinion," the teeth being wrapped around the pinion in the form of a helix. The pinion is mounted on a shaft which extends diagonally through the bed, emerging at the back of the right-hand upright, and to which the necessary reducing gears are applied. This latter form of drive, while more difficult to produce, has an advantage in the fewer reductions necessary to translate the speed from the driving means to the table. This is for the reason that a spiral pinion can be made with four or five teeth, and of a diameter large enough to key upon the driving shaft. In this drive, when properly designed, there are at all times portions of four teeth engaged with the rack. In the case of the spur-geared drive it is difficult, even with a large driving gear with a great number of teeth, to get more than one tooth in positive action at all times. It can be readily seen that with a five-tooth pinion driving into the rack, as compared to at least a twelve-tooth pinion driving through an idler into the rack, a gearing reduction equivalent to more than two to one is introduced.

Coming back to the shock of reversal of the planer platen, the designer using a drive in which the pressure is distributed over four teeth of the rack has an easier problem to solve than one in which one tooth only is counted on to take the shock.

In the planing machine in particular, the designers and builders have to thank the electrical engineers for the best solution, so far, of the problem of reversing driving means. A reversing motor having direct connection to the driving gear of the planer has been developed in capacities up to 75 hp. and both it and the control have been found to stand up successfully under the strain of continuous reversal.

The electric control of the variable-speed d.c. motor has had considerable influence upon the design of machine tools in the last twenty-five years. The facility with which speeds can be changed within the range of the motor, in the case of a drive; and the ease with which one can use remote control on motors for the adjustments, has eliminated many mechanical complications and made possible greater simplicity of design.

Pneumatic Clamping Device

Compressed air is used for some of the operations which in the smaller and earlier machine tools were performed manually. A notable instance of this is found in these same large boring and turning mills and planers. Rigidity is essential to the satisfactory performance in cutting and the crossrail of a mill or planer must be firmly clamped in position during the cutting operation. For this purpose adequate clamps are provided to the inside and outside of the housings. When it is desired to change the distance between the platen or work table and the crossrail, these clamping bolts must be released, and tightened again after setting. On a high, wide machine these bolts are in inconvenient positions for the operator to reach. To obviate this, pneumatic clamping devices are arranged so that the operator from a position on the floor can, by moving a small air valve, control either of the required operations. Fig. 3 shows one of these air-operated clamps at the back edge of an extended-back crossrail. Similar devices are located at the three other clamping points. A cylinder operates two clamps, each one acting to resist the pressure required to set up or unlock its mate. The pneumatic cylinder functions through mechanism which, when clamped, stays in that condition until positively unlocked. It is unnecessary to maintain pressure in the cylinder during the periods between adjustments. The mechanism in the pneumatic clamping devices consists in some cases of screws operating through levers with knife edges to multiply the clamping pressure, the screws being operated by levers. The clamping cylinder is connected to one of the levers, and the end of the piston connected to the mating lever. The cylinder is suspended between the two and acts as an equalizing as well as a pressure means.

Boring mills and planers have been selected from which to draw the few examples given, as being the two outstanding largest types of surface-finishing machine tools constructed up to the present time. Indications are that still larger planers and boring mills will be built in the near future than have been built before.

Automatic Punching Machine

There are other large machine tools in which developments of equal importance with those mentioned have taken place, and their design and construction offer many interesting problems. In figure 6 one such tool is illustrated. This machine is classed as a large machine tool, was designed and built by machine tool builders, yet it might be just as appropriately classified under the title of "automatic machinery." It has been distinctively named by its users the "pianola punch," this name being derived from the fact that its operation is entirely controlled by a punched paper template on a roll, similar to those used in player pianos. Compressed air controlled by the holes in the paper template, operates all of the selective mechanisms.

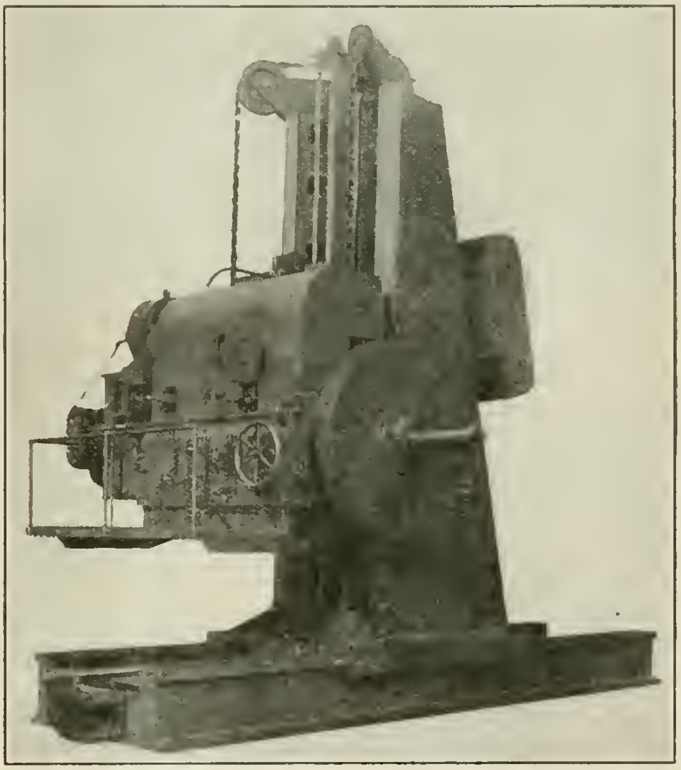

Fig. 8 Floor Boring, Drilling, and Milling Machine

(A large tool capable of handling the work of a boring mill or planer and often used for boring and surfacing castings for which a planer or boring mill of sufficient size is not available.)

The machine is of the lever type. The punches are carried on a crossbeam and arranged so that their cross-spacing may be adjusted to suit required conditions. Each punch holder is complete with a pneumatic gag-block for throwing its individual punch into or out of engagement. Spacing mechanism is provided for feeding the work through the machine in any multiple of $^1/_{16}$ in. The template which controls all of the functions of the machine is punched and proof read in some office department, brought to the machine, the work clamped in position and machine set in motion. No further attention is needed until the operation of punching the plate or angles, or both, as the case may be, is complete. Then the punch will automatically stop. Innumerable reproductions may be made from the original template, and made with great accuracy. As many as eight plates, separately punched, have been piled one upon the other and the holes registered so closely that rivet-size iron could be put through all of the plates, in any hole. The mechanism for punching and checking the paper templates is shown in Fig. 7.

The discussion on Large Machine Tools might be made to fill up almost an unlimited space; but it would seem as if the foregoing will suffice to broadly outline the general character of the work of designing and constructing large machine tools.

The Efficiency of the Scotch Marine Boiler

Results of Coal- and Oil-Burning Tests Made by the U. S. Shipping Board and the Bureau of Mines Showing the High Combined Efficiencies of Boiler, Superheater and Air Heater That Are Obtainable with Careful Operation

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THE following brief account of the tests run on a Scotch marine boiler by the U. S. Shipping Board in conjunction with the Bureau of Mines has been written with the idea of presenting to the marine world a few facts and figures in regard to the possible efficiencies and capacities that may be obtained with the Scotch marine boiler, provided it is operated with the same care in supervision as that given to the average efficient stationary plant.

From the analysis of the logs of approximately 250 vessels, it is apparent that the average merchant marine cargo carrier develops approximately 60 to 65 per cent efficiency in her boiler plant when oil-fired and that these values are from 55 to 60 per cent for coal-fired boilers. This same condition holds true for the average stationary plant of less than 1000 boiler hp., as has been shown by several analyses made at various times of boiler tests conducted on this type of plant.

The time has come, however, when better results must be obtained. The Diesel engine is rapidly entering the marine field and the steam-driven vessel must develop its maximum efficiency if it hopes to be able to sail in competition with the motorship, even after making all allowances for the relative difference in the first cost for installation.

Moreover, the merchant marine of the United States has established a higher standard of living for its operating personnel than its competitors. This higher standard means increased cost of operation, and this increased cost must be met by increased efficiency of performance.

The first essential in obtaining higher efficiencies is to educate the operating personnel to the point where they appreciate what higher efficiencies mean, how to use the instruments necessary for determining the efficiency of combustion, and how to correct faulty combustion and thereby build up boiler efficiency.

For this purpose the U. S. Navy has now opened a school at the Philadelphia Navy Yard for the benefit of the U. S. Merchant Marine, where a short and intensive course is given in the theory and practice of fuel-oil burning. Candidates for this school must be American citizens holding merchant marine licenses as second assistant or higher.

The tests which are outlined below were conducted by the U. S. Shipping Board in order that reliable and accurate data might be obtained as to the possible efficiency and capacity of the Scotch marine boiler, which is one of the oldest types of boilers in service and which has been accepted as a good, reliable servant without due regard being paid to its possible efficiency.

The Bureau of Mines was especially interested in making the thermodynamic survey of the boiler by means of thermocouple readings, gas analyses, etc., to determine the effects of combustion by the water-cooled furnace. Its findings are now being prepared by Mr. Mumford of the Bureau of Mines and his associates who worked with him and the author in carrying out these tests.

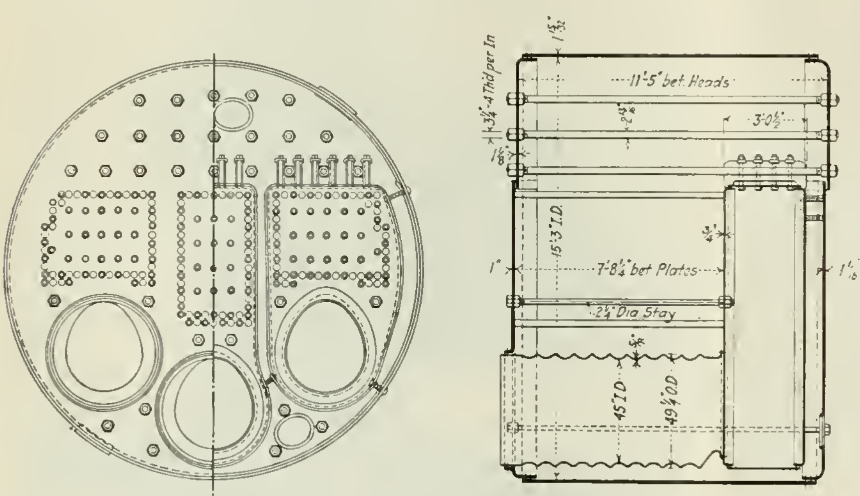

Fig. 1 General Arrangement of Scotch Marine Boiler Tested

The boiler selected for the test purposes was a single-ended, three-furnace, separate-combustion-chamber type, having 2777 sq. ft. of heating surface with coal fire and 3022 sq. ft. with oil fire. The boiler was fitted with a Foster waste-heat superheater having 774 sq. ft. of heating surface and which was placed within the gas pass above the smokebox. Above this superheater was an air heater having 1220 sq. ft. of heating surface which heated the air supply to the Howden fronts when running forced draft. Fig. 1 shows the general arrangement of the boiler and Fig. 2 that of the superheater.

Tests were divided into four distinct groups, namely, hand-fired coal, pulverized coal, forced-draft oil fire, and induced-draft oil fire. The pulverized-coal experiments were conducted to the point where it was demonstrated that this type of firing is not feasible for marine service of the Scotch boiler, as the limited size and water-cooled feature of the furnaces and combustion chambers prevented operating at ratings which were sufficiently high to meet the demand made by the average marine boiler plant.

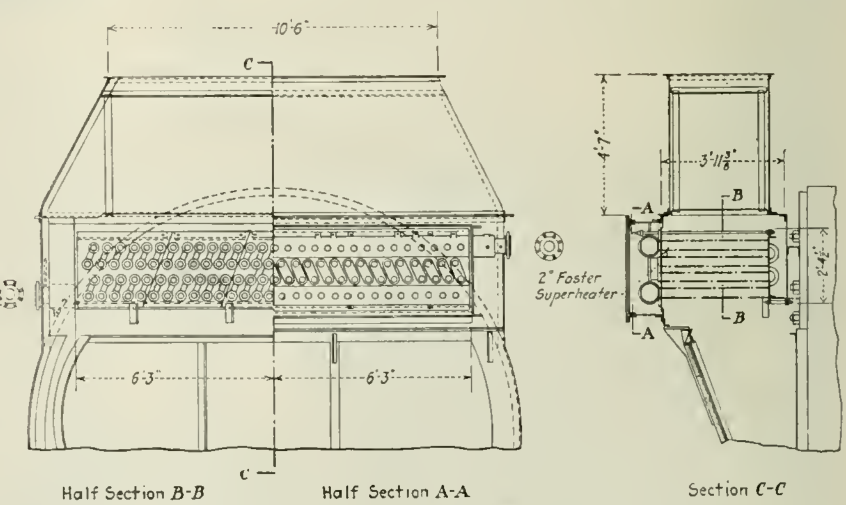

Fig. 2 Superheater Used with Scotch Marine Boiler Tested

Fig. 3 shows the boiler fitted for the hand-fired coal-burning test. In this figure the smokebox, ashpit, and fire doors are shown wide open as it was taken immediately after thorough cleaning of the

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[1] Head of Fuel Conservation Section, United States Shipping Board.

Presented at a meeting of the Metropolitan Section of The American Society of Mechanical Engineers, New York, November 14, 1922. Slightly abridged.

TABLE 1 HAND-FIRED COAL TESTS OF SCOTCH MARINE BOILER

Boiler 3 furnace, with separate combustion chambers; heating surface, 2777 sq ft. grate surface, 61.8 sq ft ; area through tubes, 11.91 sq ft ; combustion chamber volume, 289.4 cu ft ; heating surface of air heater, 1220 sq. ft ; superheater heating surface, 774 sq. ft.; retarders in tubes, bridge wall, C I V., Coal used, Georges Creek run of mine.

Test number	1-1-1-10	1-1-1-9	1-1-1-8	1-1-1-11
Duration, hr.	12.0	10.0	8.083	6.089
Total fuel fired, lb.	9,696	12,000	12,521	11,619
Fuel as fired, lb. per sq ft of grate surface per hr.	13.07	19.4	25.1	30.9
Proximate analysis of fuel				
Moisture per cent	2.15	2.27	1.97	2.17
Fixed carbon, per cent	70.93	69.87	70.00	69.44
Volatile, per cent	18.84	19.07	19.52	19.14
Ash, per cent	8.08	8.79	8.51	9.25
Heating value, B.t.u. per lb	13,329	13,779	13,858	13,683
Ultimate analysis of fuel				
Hydrogen, per cent	4.61	4.58	4.58	4.56
Carbon, per cent	80.08	79.34	79.73	79.01
Nitrogen, per cent	1.91	1.81	1.91	1.89
Oxygen, per cent	4.43	4.52	4.27	4.42
Sulphur, per cent	0.89	0.88	0.95	0.87
Ash and refuse:				
Total weight, lb.	1200	1340	1309	1125
Per cent referred to dry coal	12.66	11.40	10.60	9.90
Heating value, B.t.u. per lb.	3110	1540	4120	1938
Flue-gas analysis:				
CO_2, per cent	11.2	12.2	12.3	11.8
O_2, per cent	6.8	6.6	6.4	7.3
CO, per cent	0.07	0.2	0.3	0.02
N_2, per cent	81.88	81.0	81.0	80.88
Boiler pressure, gage, lb. per sq. in	163	157	166	158
Superheat, deg.	1	14	23	38
Moisture in steam leaving boiler, per cent	0.58	0.50	0.55	0.57
Drafts and air pressures (inches of water):				
Below grates	+ 0.19	+ 0.54	+ 0.605	+ 0.900
Furnace	+ 0.02	+ 0.16	+ 0.283	+ 0.380
Below air heater	— 0.08	— 0.058	— 0.065	— 0.090
Base of stack	— 0.12	— 0.122	— 0.092	— 0.130
Gas temperatures (deg. fahr.):				
Leaving boiler	437	503	537	606
Leaving superheater	372	447	472	519
Leaving air heater	277	336	361	396
Total water fed to boiler, lb.	100,560	124,670	122,328	116,988
Feedwater temperature, deg. fahr	212	204	193	208
Equivalent evaporated steam from boiler, lb. per hr. per sq ft. of heating surface	3.14	4.71	5.78	7.4
Actual evaporation per lb. of coal fired	10.37	10.40	9.76	10.07
Efficiency of boiler without superheater, per cent	75.2	76.7	72.6	74.6
Heat balance:				
Heat absorbed by boiler, per cent	75.8	77.9	73.9	76.8
Loss due to moisture in fuel, per cent	0.2	0.2	0.2	0.2
Loss due to burning hydrogen in fuel, per cent	3.4	3.5	3.5	3.6
Loss due to heat carried away in dry gas, per cent	6.2	7.1	7.4	9.3
Loss due to CO, per cent	0.4	0.9	1.3	0.1
Loss in combustion—ash and refuse, per cent	2.5	3.3	2.8	3.1
Loss unaccounted for, per cent	11.5	7.1	10.9	6.9
Heat in fuel as fired, per cent	100	100	100	100

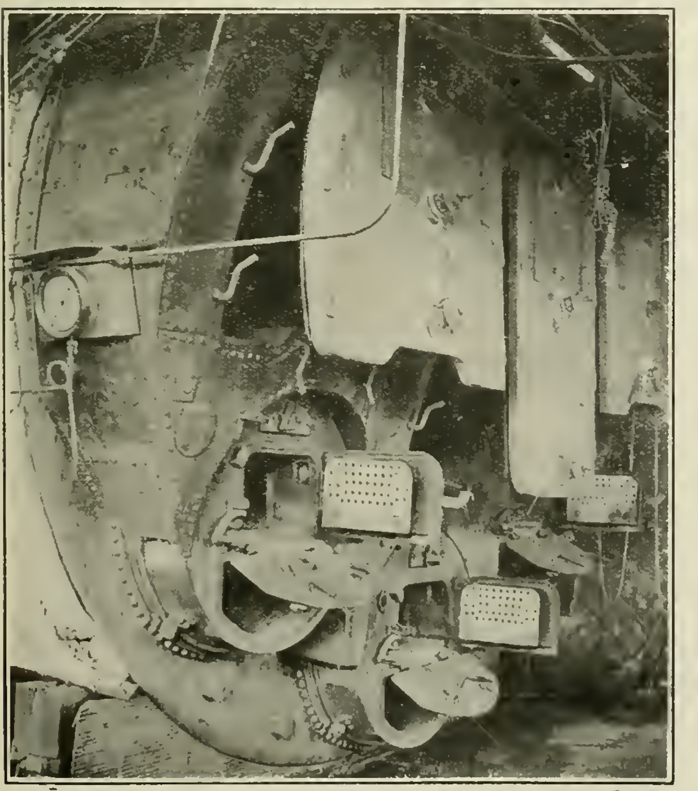

Fig. 3 Scotch Marine Boiler as Fitted for Hand-Fired Coal-Burning Test

fire side of the boiler in preparation for the test. Four of the coal-burning tests which show typical results are given in Table 1. These tests are selected as representing results covering a combustion range of from 13.07 lb. to 30.9 lb. of coal per hour per square foot of grate surface. It will be noted that the plant efficiency including boiler, superheater, and air heater ranges from 73.9 to 77.9 per cent. All of these tests were run under forced-draft operating conditions.

The forced-draft oil-burning tests were conducted using Dahl,

Fig. 4 Scotch Marine Boiler as Fitted with Burners Installed in Howden Front for Forced-Draft Runs

Schutte & Koerting, Coen, Todd, and Bethlehem Shipbuilding Corporation burners, all of these except the last named being used

TABLE 2 FUEL-OIL TESTS OF SCOTCH MARINE BOILER—HOWDEN FRONT FORCED DRAFT

Boiler: 3-furnace, with separate combustion chambers; heating surface, 3022.4 sq. ft.; heating surface of air heater, 1220 sq. ft ; superheater heating surface, 774 sq. ft.; retarders in tubes.

Test number	26	36	43
Duration, hr.	8.03	2.888	3.026
Combustion space, cu ft	561	545	588
Total fuel fired, lb.	6704	3794	6091
Fuel per burner per hr., lb.	278	438	671
Fuel per hr. per sq. ft of heating surface, lb.	0.276	0.435	0.666
Analysis of oil as fired			
Moisture, per cent	0.9	0.3	0.3
Sediment, per cent	trace	trace	trace
Hydrogen, per cent	11.9	11.72	11.6
Carbon, per cent	83.3	83.83	84.5
Sulphur, per cent	3.9	4.15	3.6
Gravity, deg. B.	15.4	15.4	15.4
Specific gravity	0.963	0.963	0.963
Flash point, deg. fahr.	166	166	166
Burning point, deg. fahr.	234	234	234
Heating value, B.t.u. per lb.	18,193	18,324	18,234
Flue-gas analysis:			
CO_2, per cent	10.8	12.3	12.6
O_2, per cent	6.3	4.5	3.7
CO, per cent	0.03	0	0
N_2, per cent	82.87	83.2	83.7
Weight of gas per lb. of fuel, lb.	19.37	16.9	16.83
Boiler pressure, gage, lb. per sq. in.	170	172	178
Superheat, deg.	24	32	45
Moisture in steam leaving boiler, per cent	0.65	0.62	0.62
Drafts and air pressures (inches of water):			
Furnace	+ 0.29	+ 0.19	+ 1.28
Below superheater	— 0.08	— 0.09	— 0.05
Below air heater	— 0.11	— 0.11	— 0.09
Base of stack	— 0.14	— 0.14	— 0.11
Gas temperatures (deg. fahr.):			
Leaving boiler	533	597	665
Leaving superheater	470	512	571
Leaving air heater	341	385	428
Total water fed to boiler, lb.	97,635	56,574	88,130
Feedwater temperature, deg. fahr.	188	218	206
Equivalent evaporated steam from boiler, lb per hr. per sq. ft. of heating surface.	4.29	6.72	10.10
Actual evaporation, lb. per lb. of oil fired	14.57	14.91	14.47
Efficiency of boiler without superheater, per cent	82.80	81.80	80.73
Heat balance:			
Heat absorbed by boiler and superheater, per cent	84.6	83.8	83.5
Loss due to moisture in fuel, per cent	0	0	0
Loss due to burning hydrogen in fuel, per cent	6.0	5.6	6.0
Loss due to heat carried away in dry gas, per cent	3.8	3.9	4.4
Loss due to CO, per cent	0.2	0	0
Loss in unconsumed oil and unaccounted for, per cent	5.4	6.7	6.1
Heat in fuel as fired, per cent	100	100	100

in conjunction with the Howden combined oil- and coal-burning front.

Fig. 4 shows the boiler fitted with burners installed in the Howden

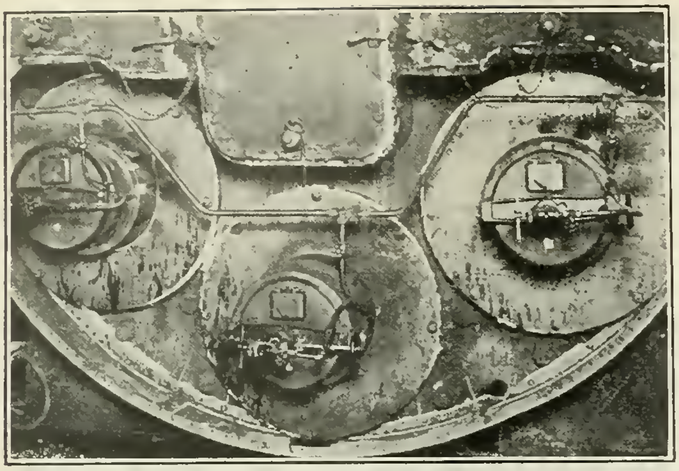

Fig. 5 Scotch Marine Boiler as Fitted with Bethlehem Burners for Induced-Draft Tests

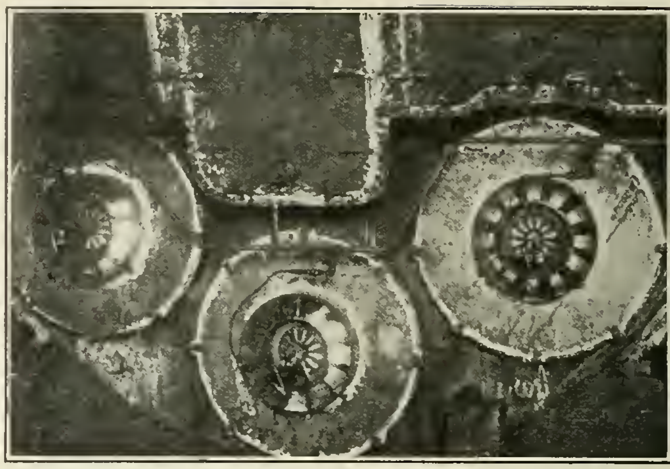

Fig. 6 Scotch Marine Boiler as Fitted with Enco Burners for Induced-Draft Tests

front for forced-draft runs. Table 2 gives the results for three representative tests of this series covering a range of from 0.276 to 0.666 lb. of oil per hour per square foot of heating surface. It will be noted that the combined boiler, superheater and air heater efficiency ranges from 83.5 to 84.6 per cent. Fig. 7 gives the average efficiency values covering the entire series of forced-draft oil-burning tests.

The induced-draft tests were conducted with the Bethlehem Shipbuilding Corporation burner shown in Fig. 5, as well as with the Schutte & Koerting types "L" (modified) and "N," the Coen,

TABLE 3 FUEL-OIL TESTS OF SCOTCH MARINE BOILER—NATURAL DRAFT REGISTERS

(Boiler same as used in tests of Table 2)

Test number	97	94	67	79
Duration, hr.	3.00	2.498	3.203	2.981
Combustion space, cu. ft.	560	560	561	564
Total fuel fired, lb.	2111	2868	4408	4625
Fuel per burner per hr., lb.	235	383	459	517
Fuel per hr. per sq. ft. of heating surface, lb.	0.233	0.380	0.455	0.513
Analysis of oil as fired:				
Moisture, per cent	0	0.1	0.1	0
Sediment, per cent	trace	trace	trace	trace
Hydrogen, per cent	11.37	11.25	11.34	11.78
Carbon, per cent	84.08	83.82	83.60	83.98
Sulphur, per cent	4.0	3.9	3.5	3.8
Gravity, deg. B.	15.4	15.4	15.4	15.4
Specific gravity	0.963	0.963	0.963	0.963
Flash point, deg. fahr.	166	166	166	166
Burning point, deg. fahr.	254	254	254	254
Heating value, B.t.u. per lb.	18,382	18,418	18,248	18,459
Flue-gas analysis:				
CO_2, per cent	12.8	13.06	12.2	11.98
O_2, per cent	3.3	3.0	4.4	4.4
CO, per cent	0.03	0.17	0.01	0.06
N_2, per cent	84.87	83.77	83.39	83.56
Weight of gas per lb. of fuel, lb.	16.48	15.95	17.19	17.49
Boiler pressure, gage, lb. per sq. in.	172	174	172	168
Superheat, deg.	0	14	28	33
Moisture in steam leaving boiler, per cent	0.62	0.64	0.62	0:47
Drafts and air pressures (inches of water):				
Furnace	— 0.14	— 0.22	— 0.31	— 0.64
Below superheater	— 0.15	— 0.25	— 0.48	— 0.78
Base of stack	— 0.15	— 0.31	— 0.57	— 0.84
Gas temperatures (deg. fahr.):				
Leaving boiler	448	525	589	548
Leaving superheater	420	473	503	490
Total water fed to boiler, lb.	32,276	41,282	61,813	66,348
Feedwater temperature, deg. fahr.	232	212	191	212
Equivalent evaporated steam from boiler, lb. per hr. per sq. ft. of heating surface	3.63	5.69	6.79	7.68
Actual evaporation, lb. per lb. of oil fired	15.29	14.39	14.02	14.35
Efficiency of boiler without superheater, per cent	82.35	78.98	79.29	78.70
Smoke, Ringlemann scale	1.5	1.75	1.5	2.5
Heat balance:				
Heat absorbed by boiler and superheater, per cent	82.9	80.2	81.1	80.6
Loss due to moisture in fuel, per cent	0	0	0	0
Loss due to burning hydrogen in fuel, per cent	5.7	5.7	6.0	6.1
Loss due to heat carried away in dry gas, per cent	7.1	8.4	9.6	9.4
Loss due to CO, per cent	0.1	0.6	0	0.2
Loss in unconsumed oil and unaccounted for, per cent	4.2	5.1	3.3	3.7
Heat in fuel as fired, per cent	100	100	100	100

the Todd, and the Enco burners. This latter burner, Fig. 6, was originated at the Philadelphia Navy Yard Fuel Oil Test Plant, and its adaptation for use in Scotch boiler service was developed during these tests.

The ratings obtained in these induced-draft tests were limited by the amount of available draft as the height of stack above the center of furnace was only 40 ft., and this draft was augmented by a ½-in. steam nozzle. The combined effect of the stack and nozzle produced an 0.9-in. draft at the base of the stack. Table 3 gives the data of four representative tests covering a range of from 0.233 to 0.513 lb. of oil per hour per square foot of heating surface and showing efficiencies ranging from 80.6 to 82.9 per cent. Fig. 8 gives the average efficiency values obtained from all of the tests of this class.

In comparing Figs. 7 and 8, the fact must be kept in mind that

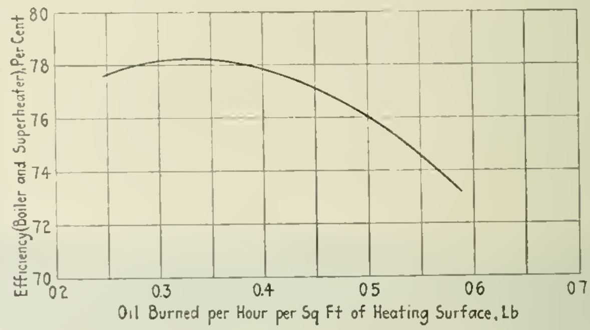

Fig. 7 Average Combined Efficiency Values Obtained in the Forced-Draft Oil-Burning Tests

(1002.46 × lb. oil per sq. ft. of heating surface = oil per burner.)

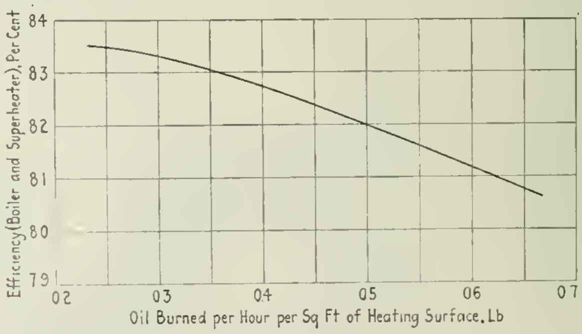

Fig. 8 Average Combined Efficiency Values Obtained in the Induced-Draft Tests

(1002.46 × lb. oil per sq. ft. of heating surface = oil per burner.)

the induced-draft tests did not have the help of the air heater in building up furnace efficiency.

From the foregoing data it will be seen that the Scotch marine boiler is capable of efficiencies considerably in excess of the average operating values obtained, and it is, therefore, a matter of simple calculation to show what considerable fuel savings are possible when reasonable supervision is shown on the part of the operating force.

Effect of Pulsations on Flow of Gases

By HORACE JUDD,[1] and DONAL B. PHELEY,[2] COLUMBUS, OHIO

The movement of gases and liquids when calculated by the existing hydraulic formulas presupposes a steady or continuous flow of the fluid. Anything which causes this flow to proceed in puffs, waves, or pulsations will result, by the action of metering devices, in errors often of great magnitude which generally do not admit of any adjustment, or of any definite knowledge of the amount of the error.

The present paper discusses work undertaken under the joint direction of the Engineering Experiment Station of the Ohio State University and the Research Sub-Committee on Fluid Meters of The American Society of Mechanical Engineers, which had for its object (1) the study of the nature of the pulsation and (2) the discovery of some practical means of reducing or eliminating the pulsation or of compensating for its effects on the devices used for measuring fluid flow. The investigation was confined to the venturi meter, the orifice, the flange nozzle meter, and the pitot meter, using air flow from a small compressor discharging into a 3-in. line. It is believed, however, that the basic principles established by the experiments are fundamental for pulsating-flow conditions for gas, steam, and water as well as for air, and also for other sizes and kinds of installations.

ONE of the most disturbing factors encountered in recent years in the metering of air, gas, steam, and water, especially in connection with all forms of power engineering, has been that due to turbulent or pulsating flow. This has not been confined to any one class or type of meter, but is present to a more or less degree with all forms of metering devices.

The measurement of gases and liquids when calculated by the existing hydraulic formulas presupposes a steady or continuous flow of the fluid. Anything which causes this flow to proceed in puffs, waves, or pulsations will result, by the action of metering devices, in errors often of great magnitude which generally do not admit of any adjustment, or of any definite knowledge of the amount of the error.

The work described in the present paper was undertaken under the joint direction of the Engineering Experiment Station of The Ohio State University, and the Research Sub-Committee on Fluid Meters of The American Society of Mechanical Engineers. A sub-committee of the Fluid Meters Committee consisting of A. R. Dodge, H. N. Packard, and H. Judd was selected to take direct charge of the research work.

Purpose of the Investigation

The object of the investigation as outlined by the sub-committee in direct charge was twofold:

a To study the nature of the pulsation

b To discover some practical means of reducing or eliminating the pulsation, or of compensating for its effects on the devices used for measuring fluid flow.

For convenience, flow meters have been classified in two main divisions which may be called (1) positive meters, and (2) inferential meters. The domestic gas, or water, meter is an example of the first class. It is a displacement meter in which an actual volume of gas is introduced into a container of known size, and the quantity thus measured is registered on the meter.

In commercial installations of even moderate size, inferential meters are used almost entirely. In meters of this class some function of the quantity of fluid passing a given cross-section of pipe is measured and from this observation the actual flow is deduced or "inferred." This method can be made to give accurate results under steady-flow conditions, but when the flow is pulsating the accuracy of the measurement is seriously affected, if, indeed, not entirely destroyed.

Three general cases may be mentioned where this problem is of great importance: (1) The measurement of natural gas, both entering and leaving a compressor station where reciprocating compressors are used; (2) the measurement of air both entering and leaving large reciprocating air compressors, or blowing engines; and (3) the measurement of steam supplied to reciprocating steam engines. The steam flow is pulsating in character because the engine cuts off the steam supply during a considerable part of each stroke. In each of these cases the flow of the fluid has a regular, comparatively rapid, rhythmical pulsation, which occasions serious errors in measurement, especially where the measuring element is of the inferential type.

Similar pulsating conditions are present in water flow where reciprocating pumps are used. The problem, however, is more easily solved by the proper use of air chambers and surge tanks. Water hammer in pipe lines from whatever cause bears a striking similarity to the pulsating effect produced by an air-compressor valve.

The authors have confined their investigations to inferential meters. These meter elements as selected are the venturi meter, the orifice meter, the flange nozzle meter, and the pitot meter. Furthermore, they have been limited to air flow from a small compressor discharging into a 3-in. line; and hence their findings, strictly speaking, would be applicable only to installations of similar character. However, it would seem highly probable that the basic principles established by these experiments would be fundamental for pulsating-flow conditions for gas, steam, and water as well as for air, and also for other sizes and kinds of installations.

Equipment Employed in the Investigation

The experimental work was carried on in the Mechanical Engineering Laboratories of the Ohio State University, and was begun in May, 1920. The essential elements for carrying on the project were: (1) a disturbing element to produce the pulsating flow; (2) a quieting element, or elements, to eliminate or modify the pulsations; and (3) a measuring element, to indicate constant flow conditions and also to indicate the effect of the pulsating flow.

Disturbing Elements. Fig. 1 shows the general layout of the apparatus, at the extreme left hand of which is located the air compressor C, a 9-in. by 9-in. single-stage, single-acting, gas engine-driven machine running at 293 r.p.m. This supplied air to a line about 120 ft. in total length of which 50 ft. was made up of $2^1/_2$-in. pipe containing several short lengths and fittings. The remaining 70 ft. comprised the 3-in. test line of straight continuous length. This test line was at first made up of standard 3-in. black pipe of commercial quality; later 24 ft. of 3-in. brass pipe was substituted for that portion of the test line preceding the meter and extending 3 ft. below the meter section. (See Fig. 1, B.)

This air supply with its full pulsating effect could be admitted directly to the test line or could be first discharged through a large tank before entering the test line. A second disturbing element for producing pulsations artificially is shown at I, Fig. 1, the butterfly-valve interrupter. This butterfly valve could be driven at speeds ranging from 180 r.p.m. to 800 r.p.m., producing thereby a variation in the number of pulsations per second.

Quieting Elements. Considerable study was made of this essential feature and many trials were made to satisfy the authors that they were securing pulsationless flow where and when needed. The tank T, Fig. 1, was used to quiet the pulsation before the meter station, M, was reached. This was a 48-in. vertical tank of 200 cu. ft. capacity. Air could be admitted either at the bottom or at the top and released from the tank through the internal pipe which reached nearly to the top. This tank when fitted with $1^1/_4$-in. orifices at top and bottom made it possible to get air flow free from pulsations before the test meters were reached.

A second quieting tank was inserted at Q, Fig. 1, at a point 8 ft. below the meter station. This was necessary in order to secure pulsationless flow at the orifice head for the purpose of establishing standard flow conditions. This tank was selected almost by chance and afterward was proved by test to be of sufficient capacity to eliminate practically all of the effect of the pulsating flow, and with

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Contributed by the Research Committee and presented at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. Abridged. All papers are subject to revision.

the insertion of a $1\frac{1}{4}$ in. orifice at the exit from the tank the authors were entirely successful in securing pulsationless-flow conditions.

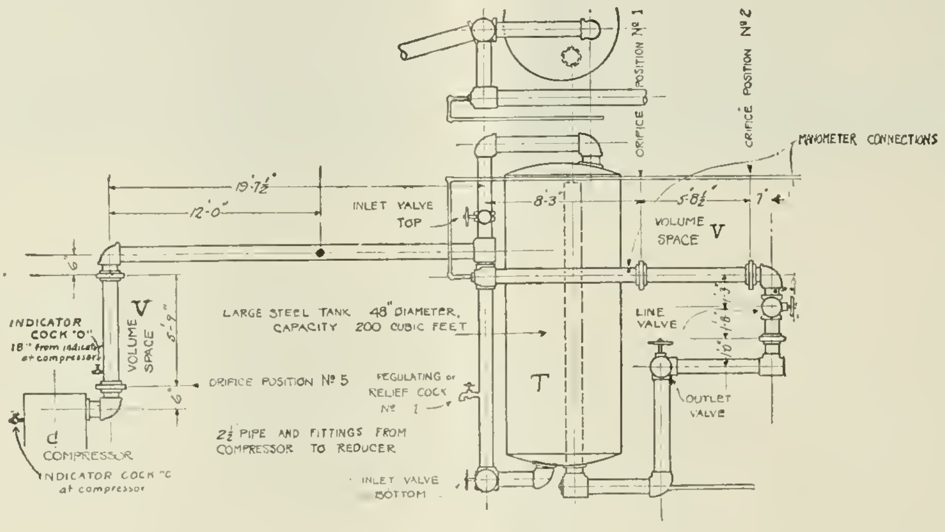
There are two positions marked, V, Fig. 1, one near the compressor and one just beyond the large quieting tank, where volumes of different sizes were inserted for the purpose of studying their quieting effect. Because the term volume seems to apply better the authors have perverted the word "volume" from a term meaning capacity to a special designation, and have used it altogether to denote the various tanks of different dimensions which have been used as quieting elements. Most of these volumes were used in the second volume space, V, beyond the large quieting tank.

The line valve near the entrance to the 3-in. test line was used as a quieting element when employed as a throttling device. Both a gate valve and a globe valve and in some cases orifices were thus used as throttling devices.

The combination of throttling with volumes constitute the muffler type of quieting device. Fig. 3, shows at *B* an S-section pipe-flange muffler which was also inserted in the line at the second volume station. This muffler is located in a by-pass in front of the line which runs directly from the compressor. All the volumes used as quieting devices were placed in direct line, but later it was found that the by-pass position answered just as well for the muffler or the other quieting devices. Fig. 3 shows sectional views of the pipe-flange muffler and also other forms of mufflers, including two funnel mufflers. A form of pulsating bag was also used as a quieting volume and was connected to the compressor line in a way similar to an air chamber on a reciprocating pump. Another device used was a system of revolving fans or baffles.

Measuring Elements. Under this heading will be taken up in order: (1) the orifice-head meter, (2) meter elements used, and (3) manometers used.

Orifice-Head Meter. It was recognized at the outset that one of the indispensable features was an accurate method of measuring the discharge of the pipe, or (its equivalent) an accurate means of indicating the velocity of the air in the pipe. This was effected



Left-Hand Portion

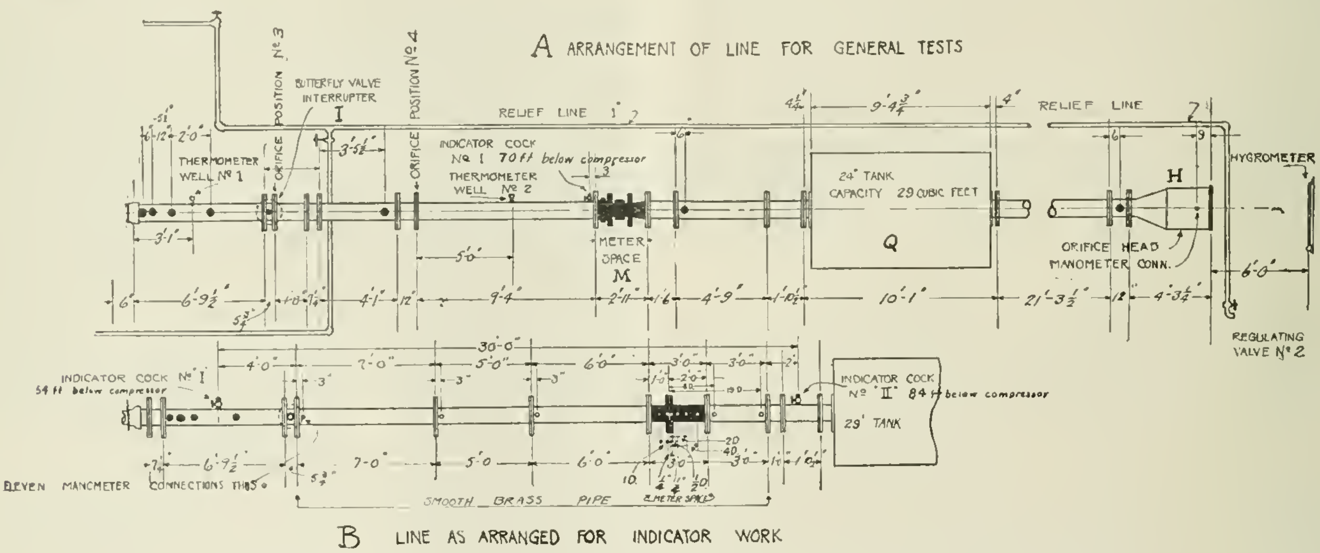


Fig. 1 General Layout of Apparatus, Right-Hand Portion (Left Hand Portion Above)

by means of an orifice head at the end of the pipe line, Fig. 1, *H*. Its outer diameter is 9 in. for a distance of 2 ft., followed by a tapered section to meet the 3-in. line. This is given a taper of 7 deg., and was so chosen as being the limiting angle for preventing as far as possible the swirling and eddying of the air as it passes into the orifice head from the line. Seven holes, reamed to $1\frac{1}{8}$ in., were provided in the head plate ($\frac{3}{16}$ in. thick), although during the tests not more than five were used at one time. In general the capacity of the compressor was reached with four holes open with a standard static discharge head of 0.9 in. of water at the orifice head. The orifice head was calibrated by discharging air through it from the calibrated tank *T* under a constant static head at the orifice head.

The orifice head was also checked against a second orifice to show how uniformly the air was distributed in its cross-section. All possible combinations of the orifices including single orifices and 5-hole orifices with and without the center orifice gave a variation not exceeding one-tenth of one per cent. This established uniform flow conditions in the orifice head regardless of the number of orifices that were open in the head plate.

Meter Elements Used. The point of insertion of the meter elements in the line, Fig. 1, *M*, was about 70 ft. from the compressor, 50 ft. above the orifice head, and 25 ft. from the entrance to the 3-in. test line.

The venturi meter was a standard unit with 3-in. entry and 1-in. throat. It is shown in sectional view at *A* in Fig. 2.

The orifice meter was made up of a flanged section of 3-in. brass pipe of the same length, 35 in., as the venturi section. The orifice flange, *B*, Fig. 2, was placed 12 in. from the upstream end and was counterbored to receive the set of orifice plates and to center them accurately. The downstream side of the hole in each plate was chamfered to $\frac{1}{32}$ in. in thickness.

The flange nozzle meter was made by inserting in the orifice-meter section a special-shaped rounded-edge orifice with projecting cylindrical end.

Two forms of pitot tips were used. The hatchet-edge static tip

(pitot No. 1) with 1/8-in. side openings is used with an accompanying open-ended impact tip with 5/16-in. opening. Both tubes are made of 1/4-in. seamless brass tubing. Also a modified form of pitot tip (pitot No. 2) was used having 3/16-in. brass tubing and an impact or leading opening facing the direction of flow and a static or trailing opening directly opposite. The diameter of each opening is 1/8 in.

Manometers Used. As far as possible the simpler forms of manometers were used. The vertical U-tube water manometer, Fig. 2, *D*, was used with the venturi meter, and part of the time with the orifice meter and flange nozzle meter, and also for the static line pressure. Where the readings had to be magnified, use was made of a 6-in. inclined one-leg reservoir oil manometer, 5 to 1 magnification (Fig. 2, *C*). For certain other readings an inclined *U*-tube oil manometer and a vertical *U*-tube two-liquid manometer were used.

A Foxboro differential mercury recording gage, Fig. 2, *E*, was used to make comparisons with the water manometer used with the venturi meter. The flow conditions were maintained and checked at the orifice head by means of an Ellison inclined gage of 1 in. range and 10 to 1 magnification.

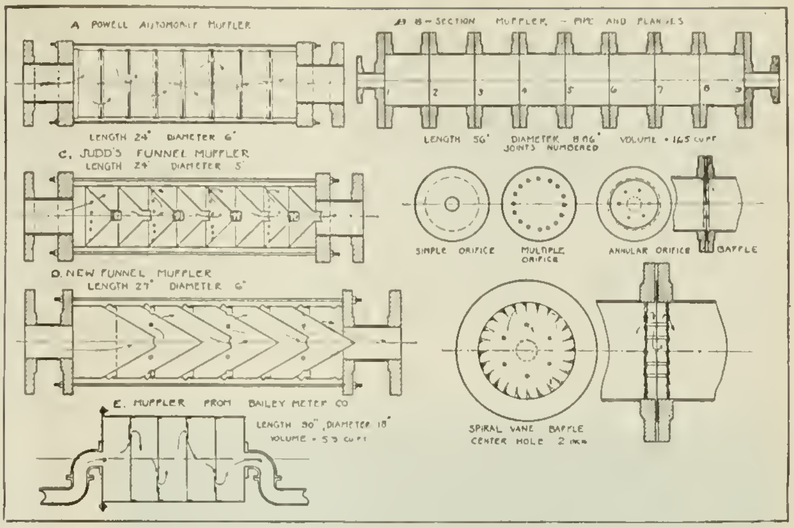


Fig. 3 Muffler Devices

Nature of the Pulsation

The first knowledge of the nature of the pulsation was gained through the use of a "photopulsometer," made and loaned to the authors by Mr. H. N. Packard of the Cutler-Hammer Co., Milwaukee, Wis. In this instrument a pitot tube with one leading and one trailing tip set with the opening in line on a vertical diameter was inserted in the center of the pipe. The leading or impact tip communicated with the under side of a diaphragm chamber. The trailing or static tip led to the upper side of the diaphragm chamber. The mica diaphragm, 0.011 in. thick, would therefore respond to changes in velocity of the air in the line as they occurred. These vibrations were directly transmitted to a mirror hung in jeweled bearings and by means of a beam of light could be thrown on a photographic film giving a diagram proportional to the velocity. By means of a pendulum beating quarter- and half-seconds a chronographic record could also be made as shown on most of the films by the breaks in the diagrams. A great many films were taken in this manner under a number of different running conditions and it proved to be a valuable method for providing a permanent record of the state of the flowing air in the line, either under violent pulsations due to various disturbing factors or for more steady flow due to the effect of certain quieting factors, as well as a record of the state of flow when under steady or pulsationless-flow conditions.

Velocity Diagrams. Figs. 4, 5 and 6, give records of the velocity changes at the center of the pipe line at various points and under various flow conditions. The maximum effect of the pulsation in the open line direct from the compressor is shown in Fig. 4. There is little or no quieting effect due to a length of pipe equal to 183 diameters.

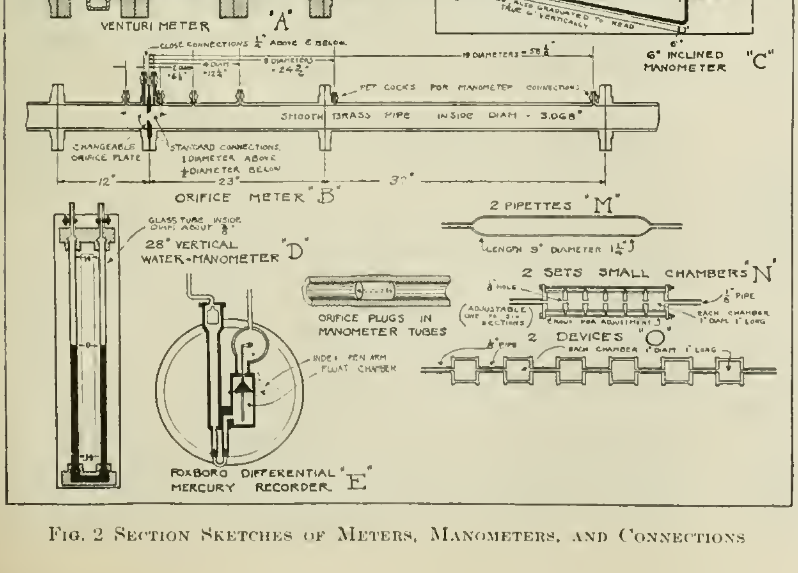


Fig. 2 Section Sketches of Meters, Manometers, and Connections

The large tank *T* was tried as a quieting chamber, when connected similar to an air chamber to a pump. However, it was found to be worthless as a quieting device. This substantiates the authors' later experience that, to be effective, tanks, or volumes, should be inserted in the line so that the air may pass through them axially.

One of the methods for eliminating pulsations is throttling by means of some kind of obstruction in the line such as a valve or an orifice. Diagram (*a*), Fig. 5, is taken for maximum pulsations direct from compressor. The diagrams appear to go below the zero pressure line, but when the secondary pulsations due to the natural period of vibration of the diaphragm are considered, it will be seen that the true diagrams approach but do not go below the zero line. Diagram (*b*) shows the quieting effect of an orifice when the pulsation has been reduced to the condition of pulsationless flow.

Effect of Pulsation of the Static Pressure in the Line. On starting the compressor it seemed frequently that the first impulse traveled much faster than the actual velocity of the air. To test this out and also to study the effect of pulsation on the static pressure in the line, two Crosby indicators were attached to the line, one on the compressor cylinder (Fig. 1, *C*), and the other 70 ft. distant (Fig. 1, *A*, No. 1 indicator) near the meter space. Diagrams were taken and two important features were brought out: (1) The pulsation in the pipe produced a much greater pressure effect than that imparted to the velocity of flow; (2) when simultaneous diagrams for a single stroke were recorded it was found that the suction stroke of the compressor corresponded to the pressure stroke in the line. This seemed to indicate that the pulsation required about the time of a compressor revolution to travel a distance of 70 ft. in the pipe. For a speed of 291 r.p.m. this would mean about 0.1 sec. for 1/2 revolution, or a pulsation velocity of 700 ft. per sec.

The Velocity of the Pulsation. The results obtained in determining the velocity of pulsation from the simultaneous sets of indicator diagrams for points located 30 ft. apart established three significant facts:

a That, although the authors' method shows results varying from the maximum to the minimum through a wide range, yet in no case does the velocity of pulsation so determined approach anywhere near the velocity of the flowing air.

b That, for a variation of velocity of flowing air ranging from zero to 27 ft. per sec., the velocity of pulsation was found to be independent of the velocity of the air.

c That the total average for 148 computations gave 1090 ft. per sec. as the velocity of pulsation. The velocity of

sound in dry air at 32 deg. fahr. and 29.92 in. barometer is 1083 ft. per sec. The velocity of pulsation in all probability is equal to that of sound in air.

For the average velocity of pulsation equal to 1090 ft. and for 4.88 pulsations per second, the pressure wave length as shown on the diagrams would be 223 ft.

Since the velocity of the pulsation is independent of the velocity of the flowing air and is evidently equal to the velocity of sound in air, it seems quite reasonable to conclude that the pulsation is a pressure change in the form of a wave front resembling a sound wave of low frequency. It seems also highly probable that these pulsations are similar in character to the pulsations set up by water hammer in a pipe line, since they also travel with the velocity of sound in water.

Some additional knowledge of the nature of the pulsation was

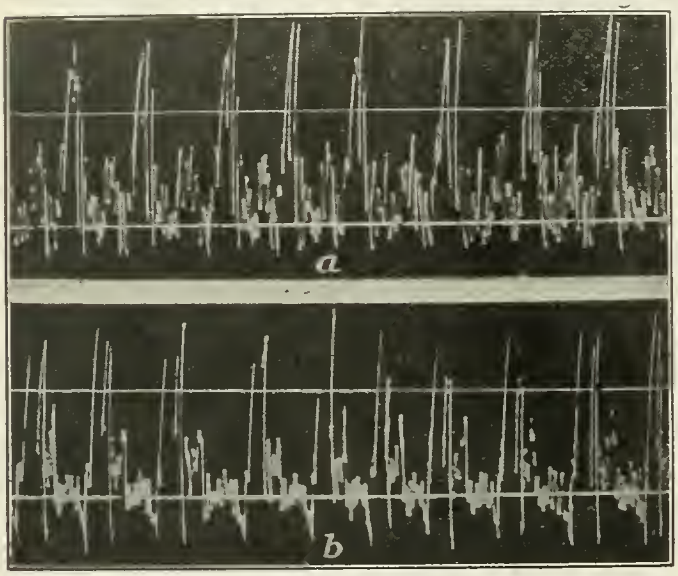


Fig. 4 Showing Maximum Effect of Pulsations at Different Points on the Line—No Quieting Effect Due to Increase in Length of Line ((*a*) Maximum pulsation in line 50 ft. below compressor. (*b*) Do., 111 ft. below compressor.)

gained by noting its effect on manometers. Where a manometer was used to measure a differential head at a meter, the following effects were consistently present:

a For pulsationless flow the reading was very constant, the only variation being a slight long period surge due to appreciable variations in the compressor speed.

b For pulsating flow this surge was magnified greatly.

c For pulsating flow there is also a rapid vibration of the water column corresponding to the pulsations and depending in amplitude upon the local conditions at the manometer.

d The most significant characteristic of the readings for pulsating flow was the large increase over that for pulsationless flow. This increase was present for every type of manometer, meter and gage tried. It varied from a few per cent to several hundred per cent under extreme conditions.

The Elimination of the Pulsation

The problem of the elimination of the pulsation, or of the effects due to the pulsation, suggested two methods of attack: (1) Modification of the existing metering devices so that the recorded flow would be unaffected whether the flow be steady or in pulsations; and (2) the use of devices which would correct or eliminate the pulsations before the flowing fluid reached the meter.

The first of these suggested schemes was taken up to some extent in the study of the modification of manometer connection. The second suggestion, that of pulsation elimination, received the major part of the authors' attention. Of the five quieting devices used, the pulsating bag and the revolving fan operated by the air flow were studied by means of the photopulsometer. The use of throttling devices, the insertion of tanks, volumes or equalizing chambers in the line and a combination of the two devices, forming the so-called "muffler," comprise the remaining three quieting and eliminating devices. These five schemes, it is believed, cover nearly all, if not all, of the practical schemes which might be used for this purpose.

Modification of Manometer Connections at the Meter. The first attempt to reduce the error of pulsation by this means was by throttling the manometer connections. It was found that throttling has no appreciable effect in reducing the error until the opening has been reduced to less than 0.07 in. diameter, and that even for an obstruction so small as nearly to close the opening the percentage of error is not reduced to within practical limits. The surge, or pulsation, of the water column was completely destroyed, so that the effect is quite analogous to that of the steam gage when throttled. This indicates that while throttling a pressure gage does not affect its reading, it has no beneficial effect in reducing the error due to pulsation.

The efficient quieting effect of volumes when used in the test line suggested the possibility that small volumes inserted in the tubes leading to the manometers might serve to reduce the pulsation before the meter was reached.

Several tests were made using the orifice meter and the 6-in. inclined gage with volumes of different sizes in one or both of the manometer connections. The results of these tests show that the use of volumes in the manometer connections does not give so favorable results as the method of throttling. There is only about 15 per cent reduction in the error for the 70 per cent orifice meter.

It was thought, also, that the point of attachment of the manometer connection might have some influence on the error due to pulsation. With the orifice meter comparisons were made with the manometer connected (1) close to the orifice and (2) at a distance of one pipe diameter above the orifice and at points below the orifice ranging from $^1/_2$ diameter to 19 diameters.

Tests made show that for all orifices including the 80 per cent

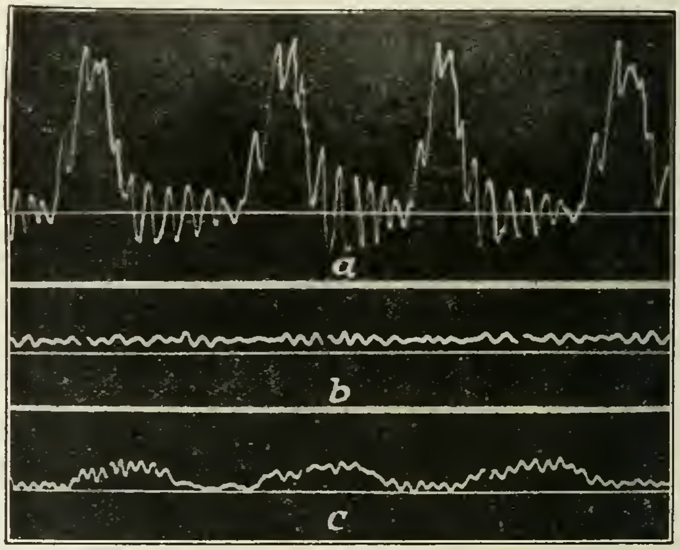


Fig. 5 Showing Quieting Effect of Throttling by Means of an Orifice ((*a*) 80 ft. below compressor, maximum pulsation in line. (*b*) 10 ft. below throttling orifice, pulsation destroyed. (*c*) 4 ft. above interrupter, 3.5 pulsations per sec.)

orifice the error at the standard points of correction is greater than that for points near the orifice which averages 96.3 per cent of the error at the standard points of correction. For points farther distant from the orifice there is a tendency for the error first to increase and then to decrease as the 19 diameters point is approaching, in all covering a total range of 20 per cent error.

Effect of Type of Manometer Used. The error in measuring pulsating flow seemed to depend to some degree upon the type of manometer used to register the head, even if all other conditions of the line and meter were identical.

It may be stated that all manometers properly graduated will give the same head readings for pulsationless flow. But when the flow is pulsating, the ratio of its reading to the true reading will differ somewhat according to the variations mentioned above. A mercury manometer will probably show an error less than that of a water manometer and the latter less than one using mineral oil. A manometer with small tubes is likely to read higher than one

with a larger set of tubes, but this is merely a tendency. If the tubes are too small the capillary effect can be noted; and if they are too large, or if they end in a reservoir, the doubtful effect due to a "volume" will be introduced. The inclined leg of a manometer under some conditions may even cause less "surge" effect. The presence of a check value or damping device between the two manometer legs or chambers, or a float to actuate the recording arm, may reduce the error.

Maximum Percentage of Error Produced by Pulsation. The results obtained show that the less the obstruction to the flow of the air, the greater the percentage of error due to pulsation; also, the greater the restoration of pressure after passing the meter, the greater will be the error. The reason for this relation appears to be that, since the pulsation is a form of pressure energy, that type of meter unit which in itself most completely dissipates the pulsation energy will show the least percentage of error.

Distribution of Pulsation as Shown by Traverse. The pipe was traversed by both types of pitot tubes for maximum pulsation conditions. The results when plotted show by both traverses that error due to the pulsating flow is least at the center of the pipe. There is a slight tendency for the point of minimum error to be located a little to one side of the center of the pipe. It is not known just how much the pitot tubes themselves are influenced by their approach to the wall of the pipe.

Quieting Effect of a Revolving Fan Section. The revolving fan apparently has some merit as a quieting device, but is of questionable practical value.

The Effect of the Pulsating Bag as a Quieting Device is shown by Fig. 6. It is felt that the special design of such a device would be needed to cover the requirement of each individual installation in order to correct or eliminate the pulsating error.

Elimination of Pulsation by Throttling. The experiments carried on with the various devices for eliminating or modifying the pulsation led to the conclusion that the solution of the problem depended entirely on the absorption of the energy of the pulsation propagated as a pressure wave closely resembling a sound wave of low frequency. Whatever the device used, its value in killing the pulsation will be measured by its ability to absorb, or dissipate, this energy of pulsation.

The general effect of throttling is to reduce the error rapidly by means of a pressure drop up to 4 in. of mercury. The use of a greater pressure drop causes the error to be reduced more gradually. In most cases the error is not reducible below 1 to 3 per cent, even with a sacrifice of a drop of 12 in. mercury. The manner of throttling is immaterial whether by gate or globe valve or by an orifice.

Elimination of Pulsation by the Use of Volumes. Tanks, or volume capacities, or "volumes," as the authors have chosen to call them, were used in the line for the purpose of quieting the pulsation. These volumes were inserted in the line so that the direction of flow through them was along the axis of the volume. They were all cylindrical in shape and with the exception of the 8-in. and the 48-in. volumes were made of thin sheet metal, No. 24 gage. It is evident from the results obtained that a volume is also a practical means of eliminating the pulsation. The chief question is, whether in large installations volumes of sufficient size would be of practical use.

Effect of Varying the Shape of Volume was also studied. In a general way a volume is probably more efficient when it is of relatively large diameter.

Elimination of Pulsation by Combining Throttling with Volumes. Since the pulsation could be nearly if not quite eliminated either by the use of throttling devices or by the use of volumes alone, the natural conclusion was that some combination of the two schemes might be discovered which would give satisfactory results without the objectionable large pressure drop or the excessive size of the volume. A series of runs was made, while the various volumes were in the line, where orifices of various sizes were placed at the entrance and exit of the volumes. The venturi and the orifice meters were used in these tests. It was found that it was possible with a volume of several cubic feet, combined with a pressure drop of about two inches of mercury, to reduce the error to a small figure, even for a meter having a large maximum error.

The Muffler as a Quieting Device. Following the experiments with the volumes and orifices combined as a means of eliminating the pulsation, the idea was further developed by the combination of a volume with several orifices; or in other words, the adaptation of the principle of the automobile muffler to the problem of pulsating flow. It was found that the effectiveness of any single type of muffler, aside from its value as a volume alone, depends entirely upon the amount of throttling produced and very little upon the design and arrangement of its baffle work.

Conclusions

The conclusions reached as a result of the investigation may be summarized as follows:

A Nature of Pulsations:

a Pulsations in a pipe line, originating from a reciprocating system, or a similarly disturbing system, consist of sudden changes both in the velocity and in the pressure of the fluid.

b The pressure change is the most apparent and is probably the greatest factor in producing errors in metering devices.

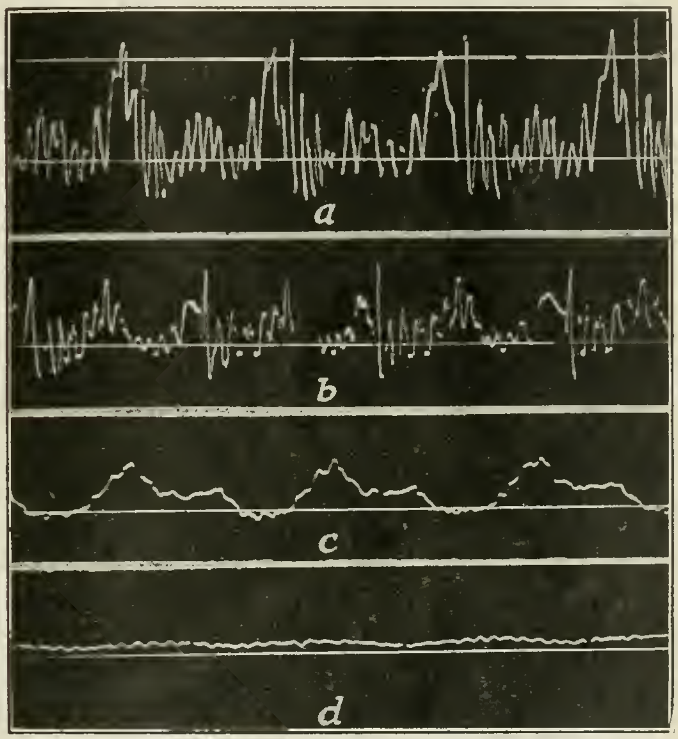


Fig. 6 Showing Quieting Effect of Pulsating Bag

(*a*) 54 ft. below compressor; maximum pulsation in line.
(*b*) 54 ft. below compressor; pulsating bag attached to quiet pulsations.
(*c*) 88 ft. below compressor; shows slight quieting effect of the 12-in. volume.
(*d*) 117 ft. below compressor; shows complete quieting effect of the 24-in. volume.

c The pressure change is in the form of a wave front resembling a traveling sound wave of low frequency.

d The pressure wave travels in the pipe with the velocity of sound.

e The velocity of the pulsation is independent of the velocity, or quantity, of fluid flowing.

f Pulsations in air flow are similar to the compression waves set up by water hammer. Both travel at the velocity of sound in the fluid and are independent of the velocity of flow.

g The effect of this pulsation on a flow meter is to increase its reading, often causing an error of great magnitude. The magnitude of this error depends upon the frequency of pulsation, nominal static pressure of the fluid, type of meter used and adjacent fixtures in the pipe line.

h With orifice meters and flange nozzle meters the pulsating error increases as the diameter of the orifice, or nozzle, approaches the diameter of the pipe.

i The throttling or modification of the manometer connections to the meter does not appreciably reduce the error.

j The point of attachment of manometer connection has no great effect on the error due to pulsating flow.

k The pulsation error at the center of the pipe is 35 per cent less than that at the wall of the pipe.

l A meter on a "dead-end" connection will usually show a positive error of considerable magnitude.

m The pulsation must be eliminated or greatly reduced in order to have the meter read without objectionable error.

B Practical Elimination of Pulsations:

n Because of the high velocity of the pulsation, an excessive length of pipe line would be necessary to destroy the pulsation.

o Throttling is effective but requires a pressure drop of 6 in. of mercury to reduce the error to 5 per cent.

p Abrupt volume enlargements in the pipe line will eliminate the error, if of sufficient capacity. A volume capacity of 20 cu. ft. is required for an error within 2 per cent.

q Generally speaking, for the same capacity, a volume of relatively large diameter is more effective than one of small diameter.

r No relation was found between the compressor displacement and the capacity of the volume chambers.

s The combination of throttling with volumes forming the "muffler" device probably is the most effective device for the mechanical elimination of pulsations.

t The pulsating bag, or diaphragm, and the fan, or revolving baffles, are partially successful in eliminating the pulsations, but their installation is thought to offer serious practical objections.

u The effectiveness of any of these quieting devices seems to depend upon their ability to dissipate or change the energy of pulsation which is effected chiefly through a drop in pressure.

v The device which will destroy the pulsating energy with the least obstruction to the flow of the fluid is the most desirable.

w The effectiveness of the meter element itself in quieting the pulsation depends upon the degree of restoration of the pressure beyond the meter. The greater the percentage of restoration, the higher the percentage of error shown for any given type of meter.

C Adjustment of Error of Pulsation:

x It is probably not feasible to correct any meter by means of a correction factor owing to the disturbing effects which may arise from slight changes in the installation and running conditions.

y The experimental establishment of a pulsating correction factor and its relation as shown in the formula proposed in the complete paper is not considered feasible with our present experimental knowledge of the laws of pulsating flow.

z It seems probable that each installation where pulsating flow is present would present its own peculiar problem for which an individual study and consideration of the existing conditions would be necessary for a satisfactory solution.

The complete paper contains additional illustrations of apparatus, indicator and photopulsometer diagrams, tables giving the data obtained in the investigation, and a bibliography of the subject. It also discusses the possibility of adjustment of errors at considerable length.

Discussion[1]

H. N. Packard,[2] who opened the discussion, said that he did not agree that the pressure change was the greatest factor in producing errors in metering devices. For instance, imagine a cylinder and piston to be discharging through a short length of pipe, including a pitot tube, into a large volume such as a gasometer. In the meter section no appreciable static pressure increase could be measured, but a very appreciable variation in rate of flow must occur with the consequent error of meter reading. As practically all meter installations were fairly close to the pulsation-producing piston, he believed the trouble caused was mostly due to actual instantaneous flow variations through the metering device.

The statement was made that at least a 6-in. mercury pressure drop was required to reduce pulsations to a practical limit. Did the authors consider this a general statement or applicable only to their test conditions? It would appear to him to be a function of the density of the fluid, its velocity and the pulsation wave form (magnitude of pulsation) if made as a general statement.

He was still of the opinion that there was some relation between the piston displacement and volume of a quieting receiver. Taking the two absurd extremes of a volume equal to piston displacement and an infinite volume, in one case it was known that no effect would be produced and in the other that perfect quieting of pulsations would occur. He believed that the quantity of fluid discharged per stroke, the number of strokes per minute, and the volume and diameter between the source of pulsations and the meter determined the pulsation effect at the meter, at least with elastic media such as gases.

On dead-end error tests he believed that there was an actual displacement of gas back and forth in the meter, this flow effect being due to the elasticity of the gas which was alternately compressed and expanded in the dead-end volume.

J. M. Spitzglass[1] wrote that prior to the advance of Professor Judd's experimental work on pulsating flow there was an idea prevalent that the error in the measurement was due mainly to the magnifying effect of the differential column, reading the average height and the corresponding square root of this average instead of the average of the instantaneous square roots which were the equivalent of the varying flow.

With the development of the flow meter, his company had sought to eliminate this error by making the meter respond electrically to the instantaneous instead of the average height of the differential column. This provision was thought to eliminate the part of the error which the authors of the paper designated as the "effect of the type of manometer used." They soon discovered that there was a much larger error due to the "harmonic" effect of the pulsations in the flow. Still, in all their observations with reciprocating flow this error had seldom exceeded 25 per cent under any circumstances. Furthermore, this error could be easily eliminated by moderate restrictions in the form of additional orifice plates on either side of the differential medium.

The effect of pulsation, according to Mr. Spitzglass' understanding of the investigation, was shown to be rather in the nature of an additional term than a factor in the algebraic expression of the flow for a given meter.

R. J. S. Pigott[2] submitted a written discussion in which he said that the problem of pulsating flow was largely an acoustic one. All the data went to show that the variability of the conditions was due to the fact that the acoustic conditions in the pipe differed with every installation, and it was hard to see how pulsating flow could be stopped in every case until a study was made of the phenomena from an acoustic standpoint.

One of the earliest problems in the opinion of the members of the Fluid Meters Committee had been that of either providing correction for the effect of pulsating flow upon the indications yielded by the flow-meter mechanism, or to so reduce the pulsations as to render their effect insignificant. The net result of research had definitely confirmed the belief that any type of meter operating on a difference of head which was proportioned to the square of velocity would register high on pulsating flow. The other belief, that it was very difficult, if not impossible, to provide suitable correction factors for the readings of the meter, was also very largely confirmed. The problem, therefore, was mainly reduced to providing commercially practicable means for suppressing pulsations to a point where they would not have a marked effect in the registration of the meter.

The experimental work so far carried out had indicated that it was feasible to accomplish this end by means of a combination of throttling with enlargement of volume. The scope of the experimental work had not been large enough as yet to definitely establish the amount of throttling and the amount of volume enlargement required for any particular case, and it was probable that the variations in velocity and size of lines would render an exact solution for any specific case difficult.

The first report of the Fluid Meters Committee was to have been produced for the Annual Meeting but the amount of work to be done both in editing the report and preparing for printing was

[1] These extracts from the discussion deal more particularly with those portions of the paper appearing in the preceding abridgment.

[2] Mech. Engr., Cutler Hammer Mfg. Co., Milwaukee, Wis. Mem. A.S.M.E.

[1] Vice-Pres., Republic Flow Meter Co., Chicago, Ill. Mem. A.S.M.E.

[2] Mech. Engr., Stevens & Wood, New York, N. Y. Mem. A.S.M.E.

too much to permit publication at that time. This report would cover the matter of installation very fully, as well as the theory and accuracy of the devices employed. It was to be hoped that it would provide for the designers and users of flow meters a complete summary of information available on the subject. Hitherto there had been no single source from which this information could be obtained, and it had been scattered through three or four hundred different publications.

John L. Hodgson[1] wrote that in his opinion, the results obtained from the elaborate researches described in the paper might have been very much greater had a careful analysis been made beforehand of the ways in which pulsating flows caused errors in meters which were based upon the measurement of a differential pressure. By making such an analysis he had found it possible to reach wider and more general conclusions than the authors and at the expense of far less experimental work. Some of the most important of these conclusions could be summarized as follows:

A pulsating air flow might be considered to consist of:

a A "pressure variation" which was transmitted with the velocity of the fluid in the pipe, plus the velocity of the sound in the fluid proper to the particular size and roughness of pipe used, and the nearness to the source of pulsation of the point where the velocity was measured.

b A "velocity variation" during which the whole of the air in the pipe was accelerated or retarded. The fluid at a point distant from the source of pulsation did not, however, change its velocity until the impulse, transmitted with the velocity stated under *a*, reached it.

Both these pressure and velocity variations caused errors in the meter, but in quite different ways.

The error due to the pressure variation occurred when the pressure pipes leading to the meter had different coefficients of discharge for inflows and outflows, and when the capacity in the meter on the two sides of the water or mercury column were different. It was then possible to obtain an actual difference of pressure on the two sides of the meter by the pressure variation alone and when there was no velocity variation at all in the pipe.

The error due to the pressure variation might easily be brought down to a very small amount by using pressure connections which had equal coefficients of discharge on both directions, and by keeping the capacities in the meter about equal.

There remained the error due to velocity variation, which was the real source of trouble. It could be shown by calculation that for certain wave forms this "velocity variation" might produce errors of several hundred per cent.

The error due to this cause could be calculated or determined by calibration for any particular conditions; but as it varied with the rate of flow, and the wave form, and the product of the specific volume and the absolute pressure of the fluid, and the loss of pressure in, and the capacity of the pipe line, it was best reduced to a small amount rather than allowed for.

The only way to reduce it was to smooth out the wave form of the "velocity variation" at the metering point. This could be done in many ways, the simplest of which (not mentioned by the authors) was to insert a capacity *and* a throttling device between the source of pulsation and the metering point. If the meter itself offered sufficient resistance it might form the throttling device; if it did not, an additional throttling device might be added. The capacity should be placed between the source of pulsation and the meter, and the additional throttling device, if any, should be placed on the downstream side of the meter.

In their closure the authors, replying to Mr. Packard, wrote that they could readily see that his type of meter would not be greatly affected, if any, by the pressure changes, even though the static pressure gage might read higher due to the pulsation. They would also conclude from their investigation that his meter would be less affected by the pulsation because the effect on the velocity head seemed to show much less error than that produced in meters depending on the pressure drop readings.

In regard to the effect produced by the static pulsation, they had failed to convey the proper meaning. The change or effect on static pressure produced by the pulsation was much greater than the effect produced on the velocity head. This pulsation, like sound, seemed to be propagated as a pressure wave and the effect produced on any measuring device, especially where difference in pressure head was used, was much greater than the effect recorded on the velocity diagrams from the photopulsometer. Hence, the conclusion that the "pressure change" was the greatest disturbing factor was drawn. This they believed to be born out in their work.

It seemed apparent that the pulsation (assuming its propagation as a pressure wave), was transmitted in the pipe by means of the air (either flowing or quiet) as a medium; and that with the dead-end meter connection the pulsation surged back and forth independent of the air which itself might also have some slight movement back and forth. This transmission of pulsation in the dead-end line would seem to be similar in this respect to the surge of pressure in a water line due to water hammer, which was very much greater in magnitude as compared with the effect due to velocity.

The conclusions given in the summary were made with reference to the installation which the authors had tested; also the reference to the throttling effects of a 6-in. mercury pressure drop considered their test conditions only, and should be modified much according to Mr. Packard's suggestion.

Referring to the relation to piston displacement of the volume of a quieting cylinder, it was probably true that *some* relation existed, but it had seemed to them that it would take such an extended investigation to establish anything approaching a law, as to render the solution impracticable.

In the dead-end meter installation, they agreed with Mr. Packard that there was an actual forward and back flow of the fluid due to the elasticity of the gas; but it was also true, they thought, that the pulsation in the form of the compression wave traveled forward in undiminished amplitude and returned in more or less diminished amplitude, depending on the length, shape, and volume of the dead-end connection.

Mr. Spitzglass stated in his discussion that the authors in finding the percentage of error due to pulsating flow had compared "a variable quantity, the pressure pulsations, on the basis of another and more variable quantity, the velocity pressure of the meter."

The error due to pulsating flow was based on the velocity, or quantity of flow, or its proportional equivalent the square root of the pressure difference through the meter element for pulsationless flow. For the four types of meters used the velocity head was equal to or proportional to the drop, or pressure difference, through the meter element. From whatever cause the pulsating flow might have been produced it was quite evident that its effect would have to be determined from the reading on the meter manometer.

It appeared to the authors, therefore, that while the pressure pulsation seemed to be the greatest factor in the error due to pulsating flow it was the velocity head reading that was observed on the meter. In their opinion it was the velocity-head readings as shown by the meter for both conditions of flow that should be compared. In fact, they were at a loss to know of any other way of establishing the percentage of error.

As pointed out in the paper and as further emphasized by Mr. Pigott, the authors believed that very little could be done to establish suitable correction factors for meters operating under pulsating flow and that the solution of the problem was reached when some suitable means were provided which would reduce the pulsations to a negligible point. The adaptation of the "muffler" device was apparently the most effective mechanical device for reducing the pulsations. However, further study and experimentation were necessary to establish the proper combination of throttling and volume space for static pressures and pulsating conditions approaching those in general practice.

Mr. Hodgson took exception to certain conclusions in the paper, in some cases justly so, and in others due apparently to a wrong interpretation. He pointed out the importance of having equal spaces in the manometer connections of the meter and in the case of the photopulsometer equal spaces above and below the diaphragm. The authors also recognized the importance of this and so far as possible all manometer connections were made of equal length, although this relation could not be maintained while the manometers were in use.

It was conceivable that the pressure pulsations might be lessened,

(*Continued on page 270*)

[1] Egginton House, Bedfordshire, England.

Some Engineering Aspects of the Design of Musical Instruments

By WILLIAM BRAID WHITE,[1] CHICAGO, ILL.

The object of this paper is to propound and answer two principal questions, namely, to what extent may the problems of producing musical tone by means of musical instruments be considered as engineering problems, and how far engineering principles and practices can be expected to work improvements in the efficiency of the most important musical instruments and in the economy and exactness of their manufacture. The major portion of the paper is devoted to the consideration of the specific problems presented in the manufacture of pianofortes.

ENGINEERING principles and practices are not at present inevitable concomitants of the making of musical instruments. Nevertheless it can be shown that musical-instrument manufacturing involves in all branches problems familiar to the mechanical engineer; and that if the principles of mechanical engineering were more generally adopted as the foundation of such manufacture, vast improvements would in due course be achieved.

Most of the present paper is devoted to a consideration of the specific problems presented by the manufacture of pianofortes, with some passing observations on player-pianos and organs. The first-named instruments occupy a position not only the most prominent in the music industries, but also the most favorable for the introduction and application of scientific ideas. Along with them, it is true, ought to be placed the various wind instruments of brass and wood, but these as yet are more important artistically than industrially; while the bowed instruments of the violin family are not practical subjects for scientific investigation from the engineering standpoint, or at least will not be such until their manufacture has reached the level of large-quantity production. Nor need there be, for the purposes of this paper, any consideration of the comparatively unimportant instruments of percussion and other minor contributors to the modern orchestra.

It is evident that any musical instrument whatsoever depends upon the recognition of, and obedience to, those laws of physics known as the laws of acoustics. Therefore it can easily be understood that scientific methods, based upon exact calculation, should form the foundation of musical-instrument building. In a word, musical-instrument building is one of the mechanical arts.

The modern pianoforte factory compares favorably with all other woodworking plants in respect to the adoption of machinery for cutting and finishing lumber and for fabricating it into wooden structures. But in regard to the tonal elements in pianoforte making, scientific reformation is imperatively needed and the present discussion is therefore confined to this phase of the problem.

The tone-producing elements in the pianoforte consist, first, of steel wires which are struck by "hammers" made of wood covered with felt. These hammers are swung on centers to which their shanks are pinned, and they move against the strings under the impulse of the musician's fingers conveyed through an elaborate system of levers, known technically as "the action." There are eighty-eight "unisons" or "notes," each consisting of two or three wires tuned to the same pitch. and each with its own hammer, its own system of levers, and its own finger lever or "key." With the rapid development of pianoforte playing since the early part of the nineteenth century, the indifferently drawn thin wires previously used had soon to be superseded by heavier material. The introduction of cast-steel wire, however, caused additional strains, which necessitated solider and stronger framework. Thus arose the now universal practice of carrying the strings of the pianoforte upon a frame or plate of cast iron. Herein lies the central engineering question of pianoforte making.

Another important tone-producing element of the pianoforte is the "soundboard." This is a sheet of spruce wood, built up from selected strips of the lumber into a square or wing-shaped table, according as it is to be used for a vertical (upright) or horizontal (grand) instrument. The strings pass over this resonance table and are put in contact with it by means of wooden bridges on which they rest, and which determine their vibrating lengths. Considering that spruce is a soft and not very durable wood and that the sheet must not generally exceed $^3/_8$ in. in thickness, it is evident that a rather heavy duty is placed upon a very slight structure in the carrying of the downward pressure of the stretched wires.

In practice the stretched wire is looped at one end over a hitch pin and then crosses the wooden bridge which connects it with the wooden soundboard. It then is stepped off at another bridge called the bearing bridge, from which it passes around the tuning pin.

Basic Conditions of the Problem

Now let the following facts be noted: First, the number of these strings or wires is about 230 in the standard pianoforte. The ten lowest (counting from the bass upward in pitch), which are also the longest, run one to a unison. The next twenty-five or so (differences exist among individual makes) run two, and the remainder, three to the unison. The tension exerted by all these wires when tuned to the standard pitch is usually not less than 35,000 or more than 50,000 lb., variations being due mainly to the individual ideas of various manufacturers as to the advantages of this or that degree of tension.

Second, the highest of these unisons (in pitch) utilizes strings each about two inches in length. At distances of an octave the string lengths are multiplied in the ratio 1:1.875, so that the increase in length from unison to unison (12 to the octave) is approximately in the ratio 1:1.054. Thus, in the largest instruments, the so-called concert grands of about nine feet overall length, the lowest bass string may be 8 ft. long. These length ratios represent the best contemporary practice, but are not necessarily binding.

Now a length of 8 ft. for the longest string on a pianoforte of this size does not, of course, represent a correct proportion, since there are seven octaves of tones. In fact, at certain points in the design of each style of pianoforte it is necessary to check the progressive lengthening of the strings, which would otherwise begin to exceed the length of the instrument, and instead to lay out each succeeding unison on the plan of increasing the weight of the wire so as to make up for the inability to increase the length as much as would otherwise be necessary. These overweighted strings are usually known as the "bass strings" or the covered strings, and form a distinct section of the design, though in a tonal sense closely related to the remaining unisons.

Third, the limitations of the human hand prescribe a total width of 48 in. for the keyboard, which is equivalent to the width of 52 white keys. The black keys are interpolated at intervals between and behind the finger plates of the white ones. Hence the entire layout of the strings, with all the arrangements for their support, must be contained in a structure which, in the largest grand pianoforte, may be as much as 60 in. wide at the keyboard end, and as much as 9 ft. long. In a small vertical (upright) instrument, the extreme width may not be more than 53 in. and the height 48 in. An ordinary grand of small domestic size will be perhaps 54 in. wide and 63 in. long.

The chief engineering problem in pianoforte design is to produce a supporting structure which will withstand the tension of the strings and provide complete stability under any normal condition of temperature or atmosphere, so that the strings will not slacken or tighten into an out-of-tune condition, and so that the soundboard shall be free to vibrate and to perform its duties as a general amplifier of the sounds set up by the vibrating strings.

Fig. 1 shows the string plan, with the bass or covered strings crossed over and above the others in order to secure the greatest

[1] Technical Editor, *The Music Trade Review* (N. Y.); Associate Editor, *The Talking Machine World* (N. Y.).

Abridgment of paper contributed by the Forest Products Division for presentation at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. All papers are subject to revision.

possible length. This is the sort of design which would be adopted for a small horizontal piano of apartment or domestic size, and is typical of present-day practice.

Tension Figures Calculated

The scale is divided into four divisions, and the strings in each have an approximate total tension as shown in Fig. 1. Assuming that the scale has been designed so that the average tension per string is 150 lb. in the three treble sections and 160 lb. in the bass section, and that there are three strings per unison to the three treble sections, then the tensions will be (proceeding from right to left): Upper treble division, 17 unisons, 7,650 lb.; middle treble division, 18 unisons, 8,100 lb.; lower treble division, 25 unisons, 11,250 lb.; which gives for the treble divisions a total tension of 27,000 lb. while for the bass section of 28 unisons of covered strings at 160 lb. per string, 18 of which are two to the unison and 10 one to the unison, we have 7,360 lb., making a complete total for the scale of 34,360 lb.

In regard to the problem of the supporting structure, the idea of a solid iron casting across which the strings shall be stretched and which shall take up their pull without putting any undue strain on the wooden soundboard, has been generally adopted since the middle of the nineteenth century. In general, the iron frames, or

marked 1 and 4 and one almost perpendicular marked 6. Struts 7 and 8 delimit the extreme treble section.

Now in most cases of current practice the struts are cast in rectangular section and are always deeper than they are wide. The cross-section of No. 3 is usually about 1.75 sq. in. in area. The cross-sectional area of the lower or hitch-pin end of the same strut is always less, owing mainly to the need for crossing it over the wooden string bridge with necessary clearance; 1.25 sq. in. is the area usually employed for the cross-section for No. 2.

The limiting strut at the lower end of the lower treble is usually designed at about 1.75 sq. in. for the part designated No. 1 and 1 sq. in. for No. 4.

Strut No. 5, limiting the upper end of the bass section, is often made with a cross-sectional area of 1.25 sq. in. and Nos. 6, 7, and 8 might be put down at an average of 1.25 sq. in. each.

It is evident that if a modified T- or I-bar construction were used, the cross-sections could be considerably smaller and the plate a good deal lighter. It is also plain that there is a torsional movement and a bending movement caused by the upward pull of the string as it crosses over the bearing bar near the tuning pin and is pressed downward under the agraffe or pressure bar, by means of which it is limited at the tuning-pin end and held tight against slippage when in tune. Fig. 3 shows the nature of this bearing.

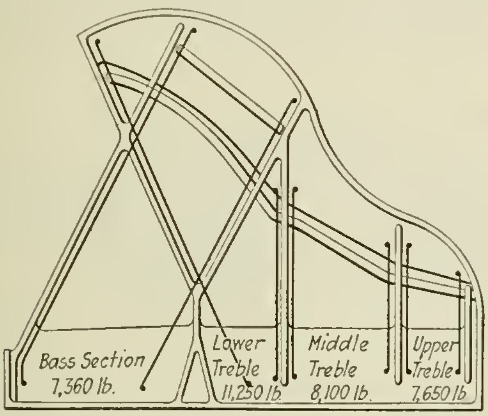


Fig. 1 String Plan and Iron Frame of a Grand Piano

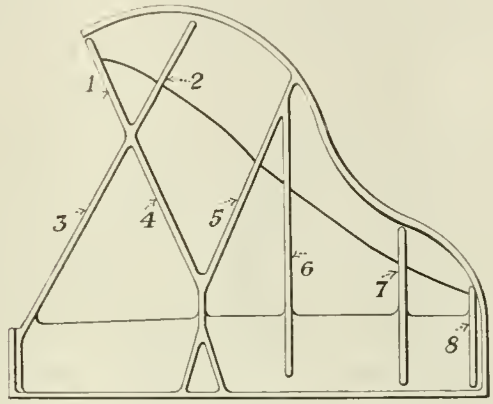


Fig. 2 Strut System in the Iron Frame of a Grand Piano

"plates," as the supporting structures are commonly called, are often far too heavy and the iron is frequently not well distributed. When they crack, as they sometimes do after the strings are first pulled up into tune, the first expedient is usually to thicken the broken member. A great deal of time, labor, and expense would of course be saved in these cases if the plate had been from the first designed by a competent engineer who could have calculated the stresses and strains and designed the tension, shear, and compression members accordingly. The relation of the strings to such a structure is incidentally shown in Fig. 1.

These iron frames, cast in one piece, fulfil two main objects: they support the tension of the strings and limit the tone-emitting lengths of these strings at the ends nearest to the tuning pins, while affording hitching places for them at the other ends. They thus consist in principle of three parts, namely, a tuning-pin plate, through which the tuning pins are driven and which is under a shear strain; a hitch-pin plate at the other end which contains the hitch pins on which the ends of the strings are fastened; and a series of compression members or struts which serve to keep the two plates at the proper distance from each other when the strings are under tension, at the same time preventing the structure from buckling. Fig. 1 shows the hitch-pin plate at the top, and the tuning-pin plate at the bottom.

Description of Supporting Structure

Fig. 2 shows the outline of a supporting structure designed to take up the strains described in the case discussed in connection with Fig. 1. It will be seen that for the bass section two struts are used, one of which has been numbered 2 and 3 and the other one 5. In the tenor or lower treble section there is one long diagonal strut

This torsional strain, and the upward pull as well, make it necessary of course to stiffen the struts rather more than would be necessary if they were to be used solely as compression members.

It should now be clear that the problem of designing the supporting structure of the pianoforte does merit the attention of engineers. In one sense of the term, the frame or plate may be deemed analogous to a truss bridge, with the differences that the load does not change rapidly and that the vibrations set up are relatively insignificant as regards any effect upon the stability of the structure.

The great need is economy of material, of resisting power, and of design, to the end that the weight of metal may be reduced, the appearance improved, the standing-in-tune qualities maintained, and duplications of the original pattern be rendered accurate and facile. It is probable also that better engineering practice would produce marked economies in the cost of production and vastly improve the general tonal standard, by securing greater uniformity and accuracy in the foundational structure of the instrument.

Acoustical Side of Tone Production

The design of the iron plate leads to a question of quite equal importance, namely, the acoustical design of the tone-producing elements or strings. Musical sounds are distinguished one from another by their pitch, relative intensity (loudness), and color or quality. The latter property, which distinguishes the sounds of one instrument from the sounds of the same pitch produced by another, exists for each family of instruments in varying degrees. Pianofortes differ among themselves greatly in quality. Some emit tones which may be described as "rounder," "fuller," or more "mellow," or again "brighter," than those of others. The differ-

ences depend upon a variety of conditions, among the most important of which are:

1 Thickness of the wire
2 Density and molecular structure of the wire
3 Tension at which the wire is stretched
4 Nature of the material with which the wire is struck
5 Point of the string at which contact takes place
6 Velocity of the hammer which strikes the blow, which is of course a function of the finger impulse upon the key.

Basis of Uniform Tone Quality

To secure tone quality as nearly as possible uniform from end to end the designer of a pianoforte should secure substantially uniform tension in each string from end to end of the scale, and an accurately graduated progression in length and weight of strings from the extreme treble to the lowest bass. The practical obstacles in the way of the attainment of this ideal are: (1) the limited number of available thicknesses of wire, (2) the limits placed upon the available lengths of pianofortes, (3) the limits beyond which bass strings cannot be loaded without destroying their tonal efficiency, (4) the fact that music wire vibrates most readily and efficiently for musical purposes at a tension equal to about one-half of its breaking strain, and (5) the uneveness of the felt used in making hammers.

To find the tension T in pounds at which a given string must be stretched so as to emit a sound of given pitch in vibrations per second the formula $T = P^2L^2M/675{,}000$ may be used, in which T is the tension required, L the length in inches, M the weight in grains (avoirdupois) per inch, and P the pitch in vibrations per second.

The design of the bass section is rather more complicated than that of the treble because the lengths cannot be determined at pleasure, but are strictly limited by the size of the pianoforte. In fact, the only rule is to make the bass strings as long as the instrument will allow, and then to calculate the weight each should have in order to give the required tension. It is better, practically speaking, to make the bass tensions a little higher, say 160 lb. per string. With this knowledge, together with the pitch in vibrations per second of each unison and the predetermined string length, the weight can be calculated from tables which have been worked out by the American Steel & Wire Co. From these same tables the nearest combination of core (steel) and covering (steel or copper) to give that weight of wire may be read off.

This is the general acoustical problem in regard to the strings themselves. The design of the supporting structure, however, can never be scientific until the string plan is just as scientific. Uniform tension properly graduated length, and carefully calculated weight are thus essential to the higher possibilities of pianoforte manufacture.

The Wooden Framework

In connection with the foundational structure there is one element which has not yet been touched upon, and which, although it is a matter of woodworking, nevertheless demands engineering attention. The strings are stretched across a soundboard and supported by the iron plate; but this plate and this soundboard must themselves be supported at their margins. The necessary support is given by a framework of wood to which, in the upright, the tuning-pin block, the soundboard, and the iron plate are fastened, and to which also are attached the sides and key bed of the instrument. In the horizontal instrument the curved or wing-shaped case, built up of veneers and bent into shape in a continuous rim around a caul, is braced by a system of beams, on which are laid the soundboard and the iron plate. Questions of stress and strain calculation naturally enter into the design of these.

Engineering Qualities of the Touch Mechanism

The practical engineer, looking at the constructional features of the pianoforte, will discover two other elements affording opportunities for improvement, namely, the touch mechanism and the stringing system. The train of delicate levers which conveys to the hammer the slightest or the boldest movement of the finger upon the balanced key lever consists of small pieces of wood pivoted on german-silver pins centered in bearings bushed with a very thick woven special cloth. Contact points are faced with buckskin or felt. There is no lubrication, and yet the total resistance to be overcome by the finger never exceeds 2.5 oz. and is usually less than this. Probably the action is the last part of the pianoforte which need engage the attention of the engineer, since it is the one part to which engineering principles have already been successfully applied.

Parallel observations may be made concerning the system of stringing. This relates to the methods commonly used to fasten the tuning pins so as to enable them to bear the torsion of the strings wrapped around them, while allowing the tension to be increased or decreased at will for tuning. The common method is to use a slim steel pin about 0.3125 in. in diameter, almost uniform in thickness from end to end, furnished with an extremely fine thread and turned into a hole drilled in a plank or block made up of cross-banded maple veneers. The total length of the pin does not exceed 2.5 in. of which about 1.75 in. is driven into the block. Many methods have been suggested and tried, successfully from the mechanical point of view, of which the object has always been to substitute a mechanical system for the crude wood block and frictionally held pin. But trade prejudice has always prevented their adoption.

Present Position of Musical Pneumatics

The rise during the last twenty years of mechanisms for playing the piano either entirely automatically or under personal control through the agency of perforated tune sheets known as music rolls,

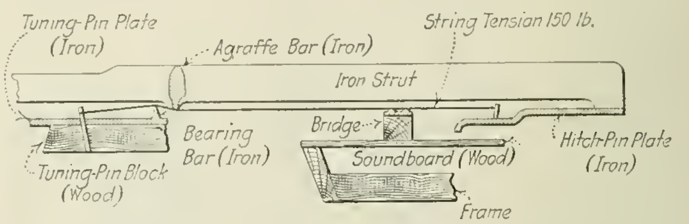


Fig. 3 Showing Method of Holding Strings Tight Against Slippage

introduces a new and fascinating set of engineering questions. These mechanisms employ, in all their forms, the pressure of atmospheric air against subnormal air pressures induced in closed chambers. That is to say, they are vacuum machines. The engineering problems they practically present may be grouped under three headings, namely, the production of the vacuum power, the prevention of leakage, and the design of the moving parts. In all these features many improvements are greatly needed. The present piano-player mechanisms are relatively crudely put together, depending upon glued-up plywood panels, rubber tubes connected with metal nipples cemented into wooden boards with shellac, and other similar devices which are clumsy, bulky, and very hard to standardize. The production of an all-metal action has been attempted, and with some success, but in practice the industry prefers to use wood, rubber hose and rubberized cloth, leather, and glue.

Problems of the Organ

The other great and complex musical instrument is of course the organ. In its many shapes, whether designed for ecclesiastical purposes, for the theater or for the home, it represents a vast complication of pipes, chests, electric contacts and cables, electromagnets, blowing engines and stop mechanisms. Unfortunately, however, the opportunities for engineering improvement are confined to the following points:

1 Blowing engine
2 Construction of the chests on which the pipes are set, with special reference to the possible use of concrete and metal in place of wood in order to eliminate the influence of temperature and atmosphere
3 Improvement in the electric mechanism which opens the pallets under the pipes when keys are depressed. Such improvement is mainly needed in order to promote durability and reliability

4 Interchangeability and standardization of parts.

These questions of interchangeability and standardization of methods, parts, and designs are the burning questions in musical-instrument manufacture. The great instruments which have been discussed are highly organized and comprehend an immense variety of parts and processes. The pianoforte draws its materials from mine, foundry, forest, sawmill, varnish factory, the sheep's back, the wire-drawing mill, from the elephant's tusks and from the sap of the caoutchouc tree.

The annual output of pianofortes is probably not to be valued on the basis of wholesale prices at more than $60,000,000 in an ordinarily good year. The industry needs, and would respond to, energetic and practical treatment from the standpoint of approved engineering practice.

Discussion at the Forest Products Session

AT THE Forest Products Session of the Annual Meeting of the Society, the following papers were presented: Some Engineering Aspects of the Design of Musical Instruments, by W. B. White; Lumber Dry Kilns, by Thomas D. Perry; Lumber Standardization, by F. F. Murray; New Factors Which Are Influencing Woodworking Machinery Design, by S. Madsen; and Control of Lumber Cutting Waste and Production, by C. M. Bigelow. The following abridged account comprises the discussion of the papers of this session that have already been published in Mechanical Engineering.

Discussion of Paper by Mr. White

Thomas D. Perry[1] opened the discussion of Mr. White's paper by asking the author if scientific investigations had been made of the resonance qualities of different woods used in the manufacture of musical instruments.

Mr. White replied that Dr. Miller, of the Case School of Applied Science, had made many valuable investigations during the past twenty years on the vibration of wood. He said that it would be highly desirable to know more about the behavior of a steel wire with reference to wood vibration and the effect on the vibration of wood of processes of preparing the wood for use.

Frederick F. Murray,[2] who said he was interested in the subject from the standpoint of the standardization of lumber, asked if wood as raw material was treated in the piano industries on the same basis that steel was treated in other industries.

Mr. White replied that the piano industry had grown from small beginnings 150 years ago until today it was including many machine and duplicate processes. The industry was still divided into a few branches, and in each of these the skilled workman did every operation belonging properly thereto. As long as such conditions existed, he said, it would not be possible to get standardization and interchangeability in the industry.

Mr. Murray said that in the furniture industry specialization had resulted in departments devoted to the manufacture of a single type of furniture, such as tables or chairs. In such shops the present standard classification of lumber was inadequate, and there was great waste resulting from piecework in shops operating on a production basis.

Mr. White spoke of the changes in the piano industry resulting from the demand for small grand pianos of the apartment size and for self-playing pianos. In all important shops, he said, there was a general standardization and a virtual interchangeability of parts. On the other hand, he said, the piano industry was essentially an art industry and the problem to be solved combined the ideals of art and production.

Mr. Murray said that standardization as he was interested in it did not mean a standardization of product nor an attempt to conform public taste to a standardized product, but dealt with the standardization of the raw material which would still admit of the most complicated fabrication. The purpose of such standardization was to eliminate the waste which now existed because of the lack of it.

[1] Grand Rapids Veneer Wks., Grand Rapids, Mich. Assoc-Mem. A.S.M.E.

[2] Hardwood Mfrs. Inst., Chicago, Ill. Jun. A.S.M.E.

Discussion of Paper by Thomas D. Perry

The discussion of Mr. Perry's paper on Lumber Dry Kilns[1] was opened by Kenneth Redman[2] who wrote that the paper inferred that the blower or forced-circulation type of kiln was suitable only for the drying of thin stock, or veneer. As a matter of fact, he wrote, the fan type of kiln was today meeting with its most marked success in the drying of extremely heavy stock which heretofor it had not been possible to dry in the pipe-coil kiln without the liability of enormous losses in the drying process. An examination of some of the fundamental facts to be considered in drying lumber would clearly show why this was possible.

Mr. Redman heartily agreed with Mr. Perry that the ideal way to dry lumber was to keep the surface pores open and to draw the moisture out of the wood at the rate that the moisture could transfuse from the center to the surface. In order to secure the maximum rate of such transfusion it was necessary to keep the outer pores of the wood open, and his experience confirmed the theory that the passing of comparatively large volumes of air so conditioned that each cubic foot would absorb only one or two grains of moisture, was by far the most speedy and economical. In other words, the fan type of kiln did not attempt to completely saturate the air, thus causing it to cool, become heavy and drop, and in this way create a circulation.

This feature of the pipe-coil kiln, regardless of its particular type, depended upon the varying density of the air in order to stimulate circulation, and consequently the drying power of moisture deficit varied directly with the length of time that the air remained in contact with the lumber. The air should be kept in contact with the lumber for as short a period as is commercially practicable so that each individual board in the pile of lumber might be subjected to air of practically the same drying power. The shorter the air travel, the more uniformly dry would be the lumber.

The principal duty of air in any drying process was to act as a conductor of heat which was transferred to the material to be dried, thus causing moisture to vaporize and then to be carried away. It was much more efficient to move air by means of a fan than to depend upon the heating and cooling effect of air.

A. A. Cutler[3] wrote in part that it would be unfair to a person wishing information on lumber kilns to let the author's statements concerning blower kilns go unchallenged. It was impossible, he wrote, to dry lumber at an even rate or in the least time unless the speed of air circulation in the kiln was rapid enough to bring each cubic foot of air in the piles back to the conditioning point before it had lost enough of its heat energy or increased its relative humidity to the point where its drying capacity was appreciably less than when it started on its circuit of drying, and nothing but a rapid circulation would accomplish this. The prevention of "interstrain" was simply a matter of conditioning the air entering the lumber piles.

If the circulation was sluggish and slow as in gravity circulation kilns, it would start to rise in the line of least resistance until the upper part of the compartment had been filled with air of the same or nearly the same temperature. Then it would gradually steep into the spaces between the lumber. As soon as it became cooler, by reason of having taken on some moisture, it would fall slowly until it got into a level of equal temperature or less humidity, where it would remain until by gradual change of kiln condition it reached the outlets at the bottom as in the case of Mr. Perry's recommended type of kiln. Hot air going up outside the pile and cold air coming down inside surely would not dry lumber evenly.

High temperatures and high relative humidities would reduce the moisture content of lumber by vaporization of moisture without creating any surface strains, but these two conditions could not be created evenly through piles of lumber without rapid circulation, and rapid circulation could not be created by anything less than a blower.

Mr. Perry had mentioned an actual operation schedule tested by practice of reducing one-inch oak from 35 to 5 per cent moisture content in 16 days. A properly constructed kiln of the blower type could do this same feat in eight days and this difference in drying

[1] Published in Mechanical Engineering, February, 1923, p. 110.

[2] Mgr., Dry Kiln Dept., B. F. Sturtevant Co., Boston, Mass.

[3] Cutler Desk Co., Buffalo, N. Y.

time was due to being able to maintain ideal drying conditions all the time in all parts of the piles.

The idea of steaming lumber in the initial drying stages, of course, did tend to even up any difference in moisture contents between the outside and inside of the lumber, but it had a very much greater value in heating the lumber to the kiln temperature. Except under conditions of 100 per cent relative humidity, the temperature of the lumber was always lower than the kiln temperature in proportion to the speed of drying. The employment of high humidities occasionally during the drying would speed up the drying time, but only in rapidly circulating kilns could this be done evenly through the piles. Within the ordinary range of kiln temperatures no damage could be done if the humidity was maintained at or near 100 per cent, but damage might be done when the humidity was reduced too rapidly. Again, it became obvious that control of humidity was very important, but how could it be accurately controlled if the circulation was so slow that widely different conditions must be created in one part of the pile of lumber before the air in another part would move out. In a blower kiln, with a speed of fourteen changes of air per minute between layers of lumber, the humidity and temperature would not have a greater difference than five per cent and five degrees, respectively.

Mr. Perry's assumption that blower kilns created too rapid surface drying was not in accordance with the facts. There might be some that did, but there were certainly others that did not, and association of rapid circulation with "too rapid surface drying" was unfair. It must be perfectly obvious that the drying rate was determined by temperature and relative humidity and that these two, so far as the conditions inside the piles were concerned, were controlled by the speed of movement of the conditioned air. Therefore, the rate of surface drying was under better control in a blower kiln than in a gravity circulating kiln.

Burritt A. Parks[1] wrote that he would like very much to have the discussion bring out more explicitly the relative advantages of the blower type and ventilated type of kilns. Among the advantages claimed for the former type were the following:

1 If the kiln is properly loaded, using end-piled trucks, a more uniform circulation of the air was obtained across both surfaces of the lumber, resulting in more rapid and uniform drying.

2 With practically all the air being recirculated, the temperature and humidity throughout the kiln were more uniform and more readily controlled.

3 Rapidity of circulation under absolute control, where a steam-engine-driven fan was used, making it possible to control kiln conditions in accordance with stock to be dried.

Some of the ventilated and condenser-type kiln advocates claimed great advantages for their kilns over the blower type on account of no power being required. This had always appealed to him as "sales talk" as the exhaust steam from a steam engine, used to drive the fan, could be used in the heating coils with a loss of only 10 to 15 per cent of its heat value in passing through the engine.

In answer to the discussers advocating the blower type of kiln, Mr. Perry said that it was obvious that there was no hope of his agreeing with them or of their agreeing with him, but he would like to call attention to two fundamentals which Mr. Redman and Mr. Cutler had not fully comprehended: First, that the maintenance of high humidity in rapidly moving air was exceedingly difficult and rarely accomplished, and second, that he knew of no means whereby a cubic foot of air would absorb only two or three grains of moisture and no more. It was his experience that the air would absorb more moisture than was desirable.

H. L. Henderson[2] asked the author what effect the periods of steaming and stewing had on the lumber. He also asked if the drying schedules put out by various kiln companies were based on moisture deficit in relation to the kind of wood being dried or if they had been worked out by experiment for a particular type of kiln.

Mr. Perry answered that very few data on the use of moisture-deficit curves for drying had been published. He believed this to be a wonderful field for the further development of scientific methods of drying. The steaming period was one which produced a complete saturation of the lumber, a complete steaming at the temperature of the room. As the process was completed there occurred another which might be better termed a cooking period, which was a preparation for the more active removal of moisture during the drying period.

[1] Byron E. Parks & Son, Grand Rapids, Mich. Mem. A.S.M.E.
[2] N. Y. State College of Forestry, Syracuse, N. Y.

Anthony S. Hill[1] asked how it was possible to know that every piece of wood in every pile had been thoroughly steamed until its center was warmed.

Mr. Perry answered that the variable elements to be controlled in a dry kiln were humidity, circulation, and temperature. Nearly every dry kiln, he said, had means for the control of humidity by the admission of water or steam to the atmosphere of the kiln. Circulation was, of course, quite clearly related to temperature and would depend on the difference in temperature inside and outside the kiln if it were of the accelerated-draft type, so that circulation and temperature had to be controlled in relation to each other. Personally he was an ardent advocate of steaming lumber. He referred to the boiling of a potato as a means of removing water from it as being in a way analogous to this process in the drying of lumber.

A. A. Hemlen said that the author had pointed out that surface moisture could be removed at almost any reasonable speed.

If it was not known how fast water could be removed from a cell without destroying it, however, the surface of the drying problem had not been scratched, he affirmed.

Mr. Perry admitted that there was much about lumber drying which was not known. The practical rule-of-thumb measure was injury to the wood, and it was known that unless a uniformity of moisture content was preserved, injury would result.

T. Cassidy said that in his plant in which the very finest woods were dried, there were kilns of almost every type, and that with good operators and careful operation, good results could be obtained in any one of them. It was a question for engineers to settle, he said, which drying method would bring about the best results in the shortest time.

R. B. Wolf[2] who acted as chairman of the meeting, asked if there was a practical method of controlling humidity conditions in a kiln.

Mr. Hill said that humidity control instruments were available, but Mr. Murray pointed out that an automatic control by such instruments was difficult if not impossible.

In closing the discussion, Mr. Perry spoke of the need of research and development in the field of lumber drying.

Proposed Classification of Oil Engines

In a paper on High-Speed Oil Engines, which was read by J. L. Chaloner before the Institution of Automobile Engineers in London, on February 15, and abstracted in *The Engineer* of February 23 (p. 202), the author said that while it has been suggested that there are too many types of oil engines to permit of a simple classification, nevertheless a detailed study of the many designs brings out the fact that they are in almost every case a modification of some fundamental principle or a combination of two or more such principles.

"Otto" has fallen into obscurity, "hot-bulb" requires qualification, "Diesel" is perplexing and inaccurate, "semi-Diesel" lacks precision, "cold-starting" is misleading, "high-compression" may refer to oil or gasoline engines, "crude oil" shows misrepresentation, and "refined oil" confesses a deficiency. Yet all the existing types can be allocated in accordance with definite ranges of pressure—whether compression pressure or maximum pressure is immaterial—and methods of fuel injection. When including high-speed engines the problems of nomenclature are certainly somewhat more complicated, because there is the tendency of the "constant-volume" and "constant-pressure" cycles to merge into each other. Mr. Chaloner accordingly suggests a system of classification of liquid-fuel internal-combustion engines under the headings (1) Gas Injection, (2) Air Injection, and (3) Mechanical Injection, each of which comprise (*a*) low-pressure, (*b*) medium-pressure, and (*c*) high-pressure engines.

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The Airship for Long-Haul Heavy-Traffic Service

By RALPH H. UPSON,[1] DETROIT, MICH.

The factors upon which the value of the airship as a carrier depends form the subject of this paper. The airship is compared with other carriers, especially the steamship, and questions of speed, route, cost of transport, and time value are considered. Design and construction methods are discussed, as are also the problems of stability, dynamic lift, mooring, and fire risk. It is not the intention of the author to treat the subject in detail, but rather to indicate the possibilities of the airship for commercial traffic and to point out the chief problems toward which the engineer should direct his attention.

COMPARING airships with other common carriers, the most closely related is the steamship, of which the airship is a logical namesake. The fundamental difference is simply one of size and weight—the boat being "inflated" with air and other materials, the airship with hydrogen or other light gas. Take any boat which floats in the water, and enlarge its linear dimensions roughly ten times, *keeping the total weight the same;* it will then float in the air and may be called an airship. But just here is where the first big problem, that of structural weight, is met. For if in this example a similar design of structure throughout is assumed, it is clear that the airship hull must be made ten times as heavy to retain the same strength as its prototype, the boat, without even considering the l/r requirements of the compression members. At this rate the airship would not even "lift" itself, and this seemingly damning fact is perfectly true as far as it goes. But fortunately its effect may be modified or even reversed by other factors which may be utilized for cutting down the structural weight.

All the opportunities for lightening the hull structure must be taken advantage of to achieve a good weight-carrying efficiency. The first of these is the possibility of arranging the loading of an airship so that tension stresses predominate in its structure, whereas compression stresses must naturally predominate in a steamship. If properly utilized, this is a great factor in the final result. In a typical Zeppelin airship, for example, about 35 per cent of the hull structure is fabric, and about 12 per cent is high-tensile wire with an effective strength two to three times that of the most efficient compression girders. Recent improvements in the shape and arrangement of the hull permit a still higher proportion of tension elements.

Next, there is a big advantage in the fact that an airship is entirely immersed in the elastic fluid in which it floats, which insures a practically uniform buoyancy throughout. The effect is modified somewhat by vagrant currents, sudden gusts, and aerodynamic instability (which will be described later), but on the whole an airship in flight is subject to outside forces much less in magnitude and at the same time more positively determinable than those affecting a steamship in a heavy sea.

It is not only in engineering methods but in materials themselves that great advances have been and are still to be made. The first light-weight, heavy-duty gas engine was developed for airship use. In metallurgy the whole development of the remarkable alloys of aluminum for structural use owes its inception to the needs of airship design. A whole paper might well be devoted to duralumin, which seems destined to replace much of the steel now used in bridges, boats, railroad cars and all other structures where lightness is an appreciable factor.

But the greatest basic factor favoring airships still remains in the consideration of *resistance to propulsion.* Given a steamship and an airship of equal gross weight and equal speed, the latter will require only about one-tenth the horsepower of the former. Or, expressed in other terms, for an equal horsepower the airship will go over twice as fast; or assuming equal power efficiency for the two types, the steamship must be of a tonnage roughly 1000 times greater. This little-known fact is the airship's real reason for existence, for it is utilized not to save power but to gain speed. A speed of 60 m.p.h. for example, which is practically impossible for a displacement type of boat, is attained by the average airship with the greatest ease. Eighty-three miles per hour has been reached and 100 miles is simply a matter of design.

Until a very few years ago this great advantage existed only in theory. Before the war the greatest speed was in the neighborhood of 40 m.p.h., in a "ship" whose structural weight was about two-thirds of the total. The airship seemed a dead issue as far as any real commercial transportation was concerned. Now, however, we are taking almost full advantage of the theoretical resistance while avoiding almost entirely the disadvantage of extra weight.

In respect to size the airship is affected in much the same way as the steamship. The weights of various parts of an airship structure vary all the way up to the fourth power of the linear dimensions. Hence beyond a certain point there is an actual increase in the structural weight per unit displacement. Considerations of power and fuel consumption, however, bring the range of economical size far beyond that of greatest structural efficiency. This is because the resistance, for equal speeds, varies as not quite the square of the linear dimensions.

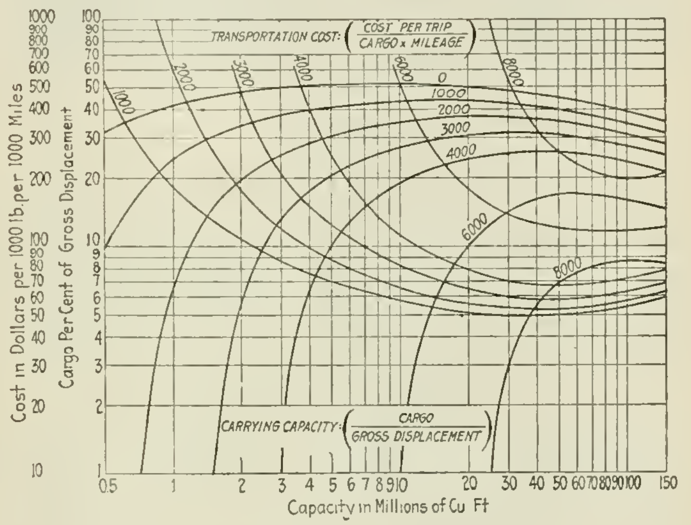

Fig. 1 Effect of Size on Airships of Similar Design, Assuming an Average Air Speed of 70 Miles per Hour

All the above factors have been taken into account in computing the data for Fig. 1, which shows the effect of size alone on freight service over routes of different lengths. The curves that are concave downward show the net cargo weight as a percentage of the gross displacement weight, the figures on the curves themselves referring to the length of route in statute miles. The other set of curves (concave upward) shows the cost of transport in dollars per 1000 lb. per 1000 miles for the different routes marked. Note especially the range of sizes marked at the bottom in *millions of cubic feet.* Remember that the largest airship in existence today has a capacity of 2,500,000 cu. ft. and see how much further we have to go to use even to fair advantage this one item of size.

But this takes care of only three of the prime factors or variables entering into the consideration of a commercial airship line. Altogether there are five: namely, size, speed, route, cost of transport, and time value. The latter is the value of time, or of saving time, per unit of passengers or cargo carried. Taking the simpler case of freight (including mail and express), if time has any value it has a money value per hour on any unit weight of the cargo carried. This may be due to its intrinsic value, to perishability, news value, or other qualities. Let us take an assumed example. In a shipment of 1000 lb. of California fruit destined for the eastern states, an average of 20 per cent spoils during the trip. The remainder commands a price of 15 cents per pound. Suppose now that a saving of 40 hr. on the trip cuts the perishability in half and the fruit, being

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Contributed by the Aeronautic Division and presented at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. Slightly Abridged. All papers are subject to revision.

fresher, sells for 5 cents a pound more. Here we have a total saving of $60 or a time value of $1.50 per 1000 lb. per hr.

Taking everything into account on a basis of present values, it seems probable that anything having a time value of $1 or more per 1000 lb. per hr. ($2 per ton-hour) can be shipped more economically by air than by rail, or about half of this figure in the case of shipping by water. This is assuming in each case the speed and size of unit best suited to the quality of goods carried.

Fig. 2 shows on a similar basis the comparison between all the available means of transportation. Here the speed is taken as net, with allowance for average stops, delays, time required to get in and out of terminals, and to load and unload. The shaded areas represent the respective economic fields to be served by steamship,

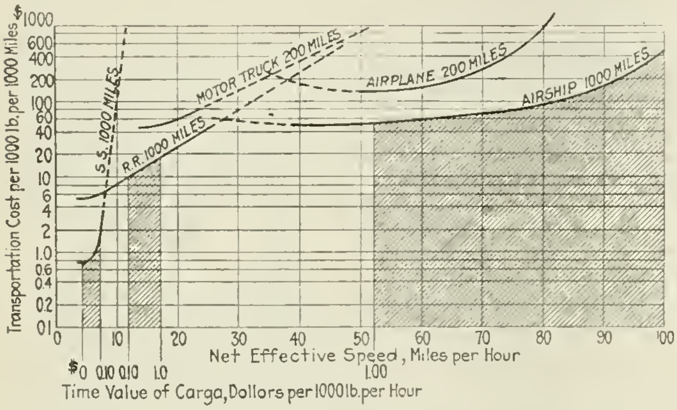

Fig. 2 Transportation Diagram Showing Economic Relations Between Different Carriers

railroad, and airship, which may be termed primary transportation units. The secondary units, motor truck and airplane, are not directly comparable with the others because their value lies in various special features peculiar to themselves. The airplane, for example, can combine high speed with small size and a comparatively short route, conditions which cannot be met by the airship.[1]

Design and Construction Methods

All lighter-than-air construction has developed from the free balloon as the basic type. Today there are five other more or less recognized types as follows:

- The kite balloon, which is the modern type of captive observation balloon
- The "blimp," a rather vague term usually applied to a small non-rigid airship with a single engine
- The non-rigid airship
- The semi-rigid airship
- The rigid airship.

The last three are only relative terms as all of them have much in common. For example, a non-rigid airship is usually stiffened as the nose in semi-rigid fashion. The usual "semi-rigid" ship is really rigid in principle, but its rigid structural parts are mainly concentrated in a keel at the bottom of the envelope instead of being partially distributed around it as in the Zeppelin "rigid." Again, it must not be thought that there is any appreciable difference in the rigidity of these different types in flight. The nomenclature merely has reference to the method of producing the necessary rigidity, the fundamental principles being the same for all.

Fig. 3 shows the Zeppelin type of construction, which is the only one so far used for the largest sizes. This consists of a sort of cage into which is put a series of large gas cells, the whole structure being covered by an outer fabric envelope. Here the non-rigid principle still exists but is confined to relatively small spaces between girders. The amount and distribution of structural elements is simply a matter of design based on the requirements to be fulfilled.

The design in general divides into two main parts: First, the aerodynamic design, in which the relations of speed, power, controllability and all external forces are worked out and correlated; second, the static design which takes care of all internal stresses and deformations, and distribution of lift and load. Calculations wherever possible are based on known laws and previous experience. But as an airship is so large and costly, and in so rapid a state of development, it is very important to have some way of checking calculations, for every new design, by experiments on models.

Problems Yet to be Solved

There are many problems connected with the control of airships which are as yet imperfectly solved. Quite contrary to what might be judged from general appearances, an airship in motion is naturally very unstable. It is not that it is subject to any sudden diving or loss of balance, for the mere mass of a large ship is enough to prevent that. Its instability is one of direction, i.e., it tends to keep on turning (either horizontally or vertically) in any direction in which it starts. Fig. 4 shows why. The air reaction or resistance at zero angle of course acts along the axis of the hull. But let the wind hit the model at even a small angle to its axis and a remarkable change occurs. The reaction is now much larger; its line of action is at a considerable angle to the wind stream, and crosses the axis far in advance of the hull itself, i.e., the hull is now acted on by a force which does not even touch it.

This instability may be made less serious by the mounting of fixed fin surfaces in the rear, but it is usually impracticable to attain complete stability in this way; so that we must still depend to a large extent on the rudders and elevators. The function of these is then not so much to turn as to keep from turning; in fact, a gradual turn requires the rudder to be held in just the opposite direction to prevent turning too sharply, and often to hold a given angle with the horizontal requires an elevator action opposite to what might be casually supposed. The development of satisfactory stabilizing means would take considerable strain off the pilot, make for a straighter flight path, minimize unpleasant motions, and facilitate mooring.

Another feature that may be appreciated by reference to Fig. 4

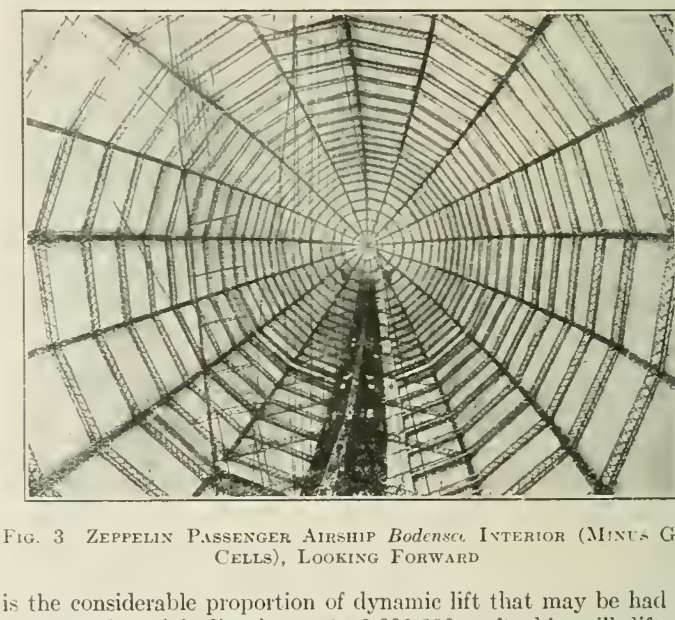

Fig. 3 Zeppelin Passenger Airship *Bodensee* Interior (Minus Gas Cells), Looking Forward

is the considerable proportion of dynamic lift that may be had at small angles of inclination. A 2,000,000-cu-ft. ship will lift in this way an *excess* load of 3 tons or more at full power. The lift is there—there is no doubt about that—but the problem is how to utilize it. An enormous airship cannot be started by running it along the ground like an airplane. It would be as easy to put wheels on an ocean steamship and run it on land. But some method of taking on the extra load and carrying it safely after the airship gets under way is at least a possibility and should be carefully investigated.

The way this dynamic lift functions now is generally in a reversed direction. The ship starts up approximately balanced, but changes in altitude and temperature are sure soon to cause variations in the lift which are compensated for by use of the elevators. These changes are not usually serious for a high-powered ship, but it is decidedly otherwise as regards the gradual consumption of fuel on a long trip. This is compensated at first by tilting the ship down

[1] Aerial Transportation of the Immediate Future, *S.A.E. Journal*, June, 1921, p. 593.

to get a negative dynamic lift, but eventually it becomes excessive even for straight flight and far more than is possible to land with. Then there are only two alternatives, either to let out gas or take on ballast. The latter, where possible, is the safer and cheaper. Two devices for this purpose are being developed at the present time; one is a trailing pump for taking water up from the ocean or other body of water; the other is an apparatus for condensing the moisture out of the engine exhausts. By the latter method more water can be collected than the original weight of the fuel, but the condensing apparatus so far developed is clumsy, heavy, and not entirely satisfactory. Another idea that has been used with some success is to burn the surplus hydrogen in the engines, thereby getting a reserve of fuel. This is a valuable recourse for emergencies, but hardly a substitute for the taking on of ballast, whose principal object is to prevent using up the gas reserve.

Another problem largely aerodynamic in character is the mooring and housing of a large airship. The resistance of a ship set approximately crosswise to the wind is commonly 30 to 40 times the amount of the head-on resistance. Hence the main principle of mooring in the open is to keep the nose headed constantly into the wind. In this position it will easily withstand any wind that blows.

The "mooring mast" as used in England, in which the wind itself is supposed to keep the ship in proper alignment, is not entirely satisfactory. In the first place, it takes great skill to bring an ordinary unstable ship up to a mast at all without breaking something. Then, even after it is moored fast, the ship will yaw through a considerable angle, putting corresponding strains on the structure. In a vertical plane the wind stays fairly near horizontal, but the ship does not, owing to the unavoidable changes in lift and trim. Furthermore, the ship is in a very inconvenient position for loading, unloading, inspection, and repair. But the most permanently serious problem of all those concerned with outside mooring may well be that of snow. A heavy snowfall without much wind would soon pile up a dangerous weight on the huge surface of the envelope and fins. Without other provisions for taking care of such a situation, the safest thing to do would be to cast loose and fly south with the birds!

Finally, any exposed mooring with the present rather perishable envelope fabric may be said to be an extravagence rather than an economy for any regular operation. Nevertheless, with metal envelope and other improvements the author believes that the time is not very far distant when an airship will remain in the open as a matter of course and only be brought into a hangar as a steamship is put into drydock, i.e., for general overhauling and special repairs.

Fire Risk

In addition to such problems, which range all the way from details to general construction, there is the fire risk, which seems to be the one considerable danger in airship operation.

It may be said at the start that the danger from fire is no doubt greatly exaggerated by many people mainly due to the accidents which befell the *R. 38* and the *Roma*. For airships there are no data by which we can estimate the risk on a percentage basis, for no regular passenger on an airship line has ever been lost, and no airship, aside from military and experimental ones, has ever burned

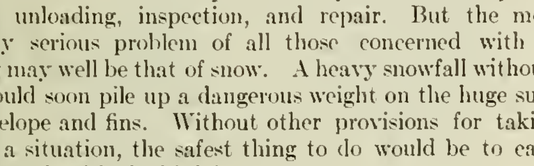

Fig. 4 Air Reactions on a Stream-Line Hull for Varying Angles of Pitch and Yaw

(Figures refer to inclination of wind stream relative to axis of hull.)

in the air. The Zeppelin passenger ships have carried approximately 40,000 passengers a distance of over 3,000,000 passenger-miles with never a fatality or serious injury. Nevertheless, the fire danger obviously exists and everything possible must be done to eliminate it.

In a present-day airship there are three principal inflammable elements: hydrogen, gasoline, and fabric. All three have possible substitutes, the most available being helium, heavy fuel oil, and metal, respectively.

The use of helium removes the largest bulk of inflammable material, but it is a mistake to suppose that the fire risk can be eliminated by this means alone. Hydrogen will not explode unless mixed with air, but it will burn if ignited by some outside agency at a point where it meets the air. For example, suppose a gasoline fire in one of the cars spreads to the envelope and ultimately reaches the gas. If the gas is hydrogen it will of course burn as it rushes out, at the same time rapidly accelerating the burning of the envelope. This is what happened to the front half of the *R. 38* after it broke in two. The use of helium would have been no insurance against the outer envelope burning away, and with it enough of the inner fabric to liberate all the gas; but the action would undoubtedly have been enough slower in that case to have saved many lives.

To eliminate the gasoline hazard, as well as to provide more economical fuel, there are several promising developments of heavy-oil engines now in process. This type of engine should be specially suited to airship work, which requires constant running for long periods of time.

To make the airship structure itself fire-resisting, the most feasible means seems to lie in a more extended use of duralumin. An all-metal envelope promises not only protection against fire but great improvement in durability and other desirable qualities as well. The metal ship of the future, especially if provided with heavy-oil engines, will be virtually fireproof as far as commercial service is concerned. It can thus be independent of the use of helium, which is rare, expensive, and deficient in lift. For military purposes, however, all three of the above-mentioned safeguards would be desirable.

Conclusion

To sum up the situation in general, it may be said that the improved airship will be definitely available for commercial traffic over either land or water in rough proportion to the extent to which the following conditions exist:

- Length of route (should be 500 miles or more)
- Density of traffic (at least 200 passengers or 50 tons of goods per trip)
- Time-value of pay load (passengers' time worth \$6000 per year or more; goods \$2 per ton-hour)
- Favorable meteorological conditions (no definite minimum).

The New York-Chicago route, which is so favorable in other respects, is the very worst in the country from a weather standpoint. A thorough analysis of this route by the Zeppelin Company shows the following results for present means and methods. A nightly 12-hr. service in both directions can be maintained 100 per cent on time for a season of six months. For the full year, however, the on-time trips would be cut to about 93 per cent. (An average of 4 per cent of the trips would probably be postponed or cancelled by advance notice, to enable prospective passengers to go by train if they so desired.)

A 60-hr. (average) transatlantic service could be maintained practically the year round.

The technical requirements of such a service are fairly clear, but the business side of it presents one of the hardest problems that have ever come up. In any other kind of transportation men have had the privilege of starting out with small units which, under favorable conditions, could at least pay their own way. With airships, however, it is necessary to choose between the frying pan and the fire. Either we must start with a comparatively small unit and a certainty of losing money on it or take a chance with large units on which we may lose a great deal more before they can be made profitable. It is indeed a great temptation to spend the larger amount of capital for what may look like good profits from the start. But it must be remembered that it is a new enterprise, entirely untried in this country; ships of the necessary size and construction have never yet been built; the whole system of safe and economical operation must be developed; and conjointly, the public must be educated to use the service. It is a maze of interreacting factors like the stresses in an airship hull itself, but much more indeterminate, and should certainly be as frankly recognized. A single ship of the smallest practical size (which is quite large and costly enough) to try out a given route will be well worth what it costs if it contributes but a small percentage to the "success insurance" of the larger enterprise.

Hydraulic-Transmission Variable-Speed Drive for Machine Tools and Manufacturing Processes

By WALTER FERRIS,[1] MILWAUKEE, WIS.

"Hydraulic transmission" has been in course of development as a variable-speed drive for twenty-five years, and has often been applied to gun control, turret control and steering gears on naval vessels during the past fifteen years. Its accuracy and flexibility of speed control, mechanical efficiency, durability of mechanism, and ability to stand abusive accelerating and stalling loads without overheating are well established, yet this type of drive has never attained extensive introduction in the industries, where its most extensive field seems to lie.

The author describes and illustrates a number of applications of the "Oilgear" to machine-tool driving, broaching, hydraulic presses, etc. This device is based on the same principles as earlier hydraulic transmissions, but has been developed from the beginning (in 1909) with a view to industrial requirements first, and automotive and marine applications afterward. The results obtained in practice during the past five years would apparently indicate that this method opens a field in which great improvements in machine-tool design may be made.

THIS paper is a report of progress made in applying "hydraulic transmission" variable-speed drive to machine tools and ordinary manufacturing processes, as distinguished from its previous applications to gun control and other naval work. In undertaking to develop a type of hydraulic transmission which should be commercially available, the designers of the device described later have purposely avoided the obvious field offered by the automobile, choosing instead the wide field of machine-shop drives and general manufacturing purposes. In this field the rigid requirements of extreme lightness and compactness do not apply, while the need of a satisfactory drive which will give any desired speed is just as great as in the automobile.

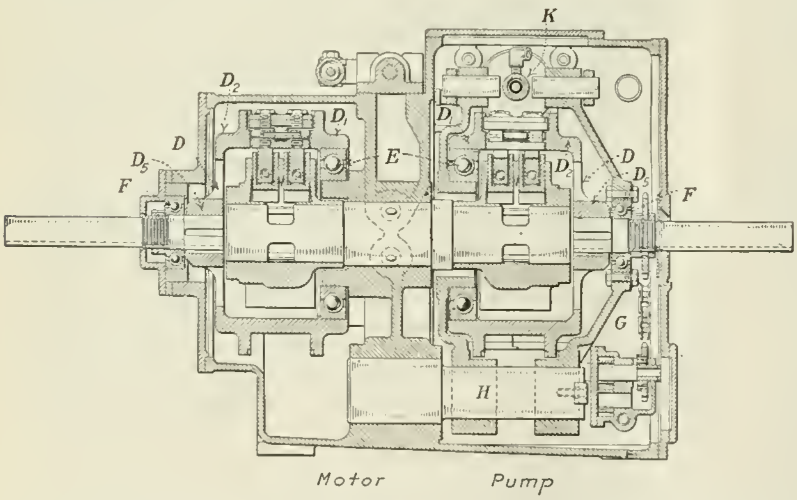

Fig. 1 Oilgear Hydraulic-Transmission Variable-Speed Drive, Longitudinal Section

Every hydraulic transmission comprises a pump, a motor, and a liquid circuit connecting them. For the driving of machines in machine shops and for general manufacturing we may add the conditions that the pump shall be a plunger pump, that it shall have a sufficient number of plungers to give a practically uniform flow, and that the stroke shall be adjustable at the will of the operator. Also, the only power-transmitting liquid herein considered is oil.

The various types of variable-speed hydraulic transmissions all employ multi-cylinder plunger pumps, and may be divided according to the arrangement of their plunger groups into axial and radial machines. Axial machines have cylinders arranged like the chamber of a revolver, parallel to and surrounding the drive shaft. Radial machines have cylinders arranged like the spokes of a wheel. In all cases there is an oil circuit having high-pressure ports and a conduit leading from pump to motor, and low-pressure ports and conduit from motor back to pump. In all cases several pump plungers are acting at once in communication with the high-pressure port, and several others in communication with the low-pressure port. This feature gives a uniform flow of oil. Some machines run with all working parts submerged in oil, and some with "empty case" and an oil sump below the level of the working parts. All have one member carrying a group of cylinders and another member operating the plungers in those cylinders, with the plunger stroke variable by the operator.

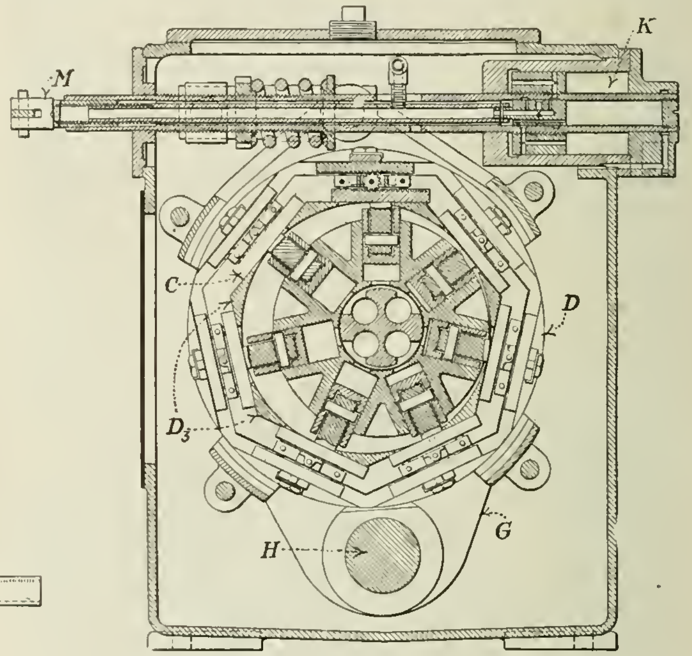

Fig. 2 Transverse Section Through Center of Pump

Design of the Oilgear

The Oilgear machine is of the radial type, its arrangement being shown in the longitudinal section (Fig. 1) of a unit containing both pump and motor mounted on a double-ended pintle and the transverse section (Fig. 2) through the center of the pump.

Fig. 3 shows the unit with two handhole covers removed, through which all of the plungers in both pump and motor can be withdrawn for examination if required. To remove a plunger it is only necessary to slide out a reaction plate A (Fig. 4) which is plainly visible through the open handhole, after which the roller-bearing cage B is removed and the crosshead with the attached plunger or plungers may then be withdrawn. It will be seen that each driver D (Figs. 1, 2, and 4) comprises two complete rings or flanges D_1 and D_2, integrally united by seven posts or bars D_3. Flange D_2 also carries hub D_5 into which the shaft is pressed, and the entire revolving driver D is supported on ball bearings E and F.

In the case of the pump these ball bearings are carried by a swinging cradle G (Figs. 1 and 2), which can be swung to the right or left around a stub or pivot shaft H. This serves to change the stroke along an arc of large radius, in place of the rectilinear slide used in the other radial machines. Figs. 4 gives details showing the plunger and crosshead unit with roller bearing, reaction plate, etc., in their relation to the driver. The thrust of the Oilgear plunger is

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Contributed by the Machine Shop Division and presented at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. Abridged. All papers are subject to revision.

delivered directly against the crosshead C, and thence through a roller bearing B to a corresponding reaction plate or roller path A carried by the driver D. There are no wristpins or rubbing bearings of any kind. The pressure on the plunger is limited only by the capacity of the roller bearing, which also reduces the friction almost to zero. The pins C_3 (Fig. 4) are not wristpins, but merely loose retaining pins to hold the parts together until the assembly

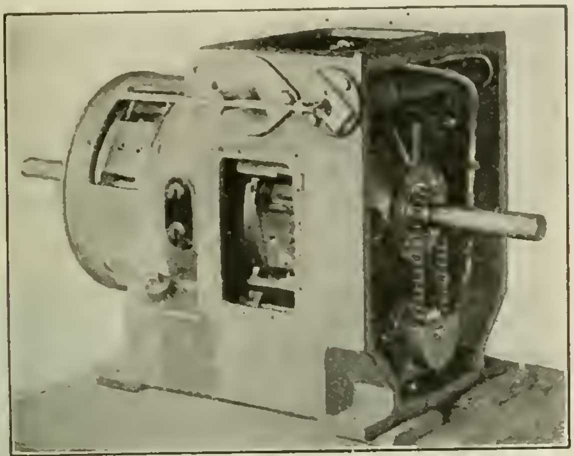

Fig. 3 Oilgear Machine with Handhole Covers Removed

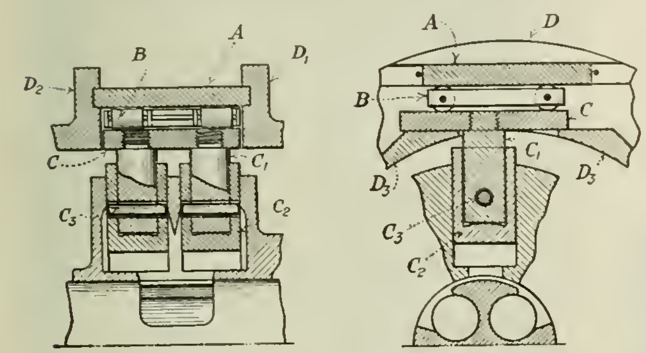

Fig. 4 Details of Plunger and Crosshead Unit

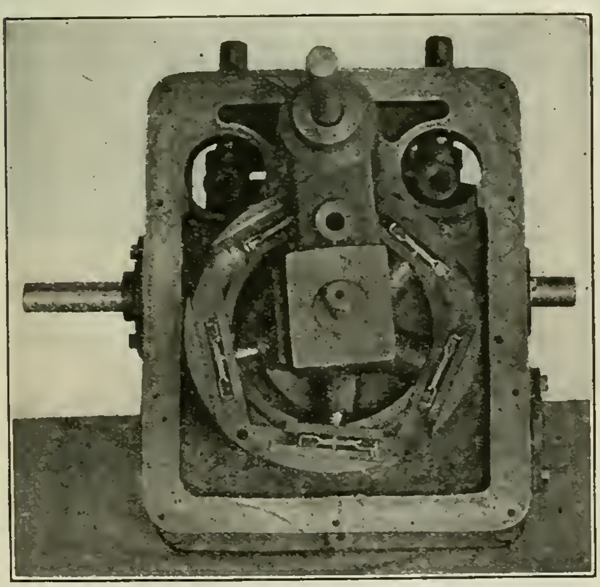

Fig. 6 Variable-Delivery Portion of QC Control Pump

is complete. All angular thrusts and side friction on plungers are eliminated. Figs. 1 and 2 also show the hydraulic stroke-changing mechanism K controlled by the pilot-valve stem M.

This paper is not intended to give a full discussion of the theory of the Oilgear, which in most points is similar to that of other hydraulic transmissions, but it is necessary to describe one special form before passing on to the applications. Fig. 5 shows a small Oilgear known as the QC control pump, connected to an ordinary double-acting cylinder operated thereby. Figs. 6 and 7 show the interior construction and working parts of the pump. The casing shown contains the pump only, the cylinder in Fig. 5 acting as the motor. This is in effect a hydraulic press, and it will be alluded to in that connection in a number of the applications subsequently described.

This control pump comprises the combination of a small variable-delivery pump, Fig. 6, with a large constant-delivery pump (the gear pump, shown at K in Fig. 7, and occupying the lower part of the unit) combined with it in the same casing and operated by the same drive and control. The machine also contains a distributing valve (J, Fig. 7) which is connected to the operator's handle on top of the case (Fig. 5). This handle may be moved from its central or zero position 90 deg. in either direction. During about

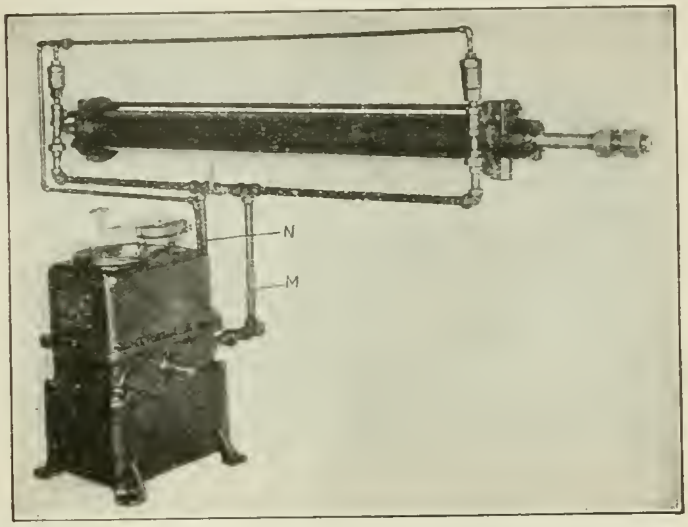

Fig. 5 QC Control Pump, in Casing, Connected to Double-Acting Cylinder

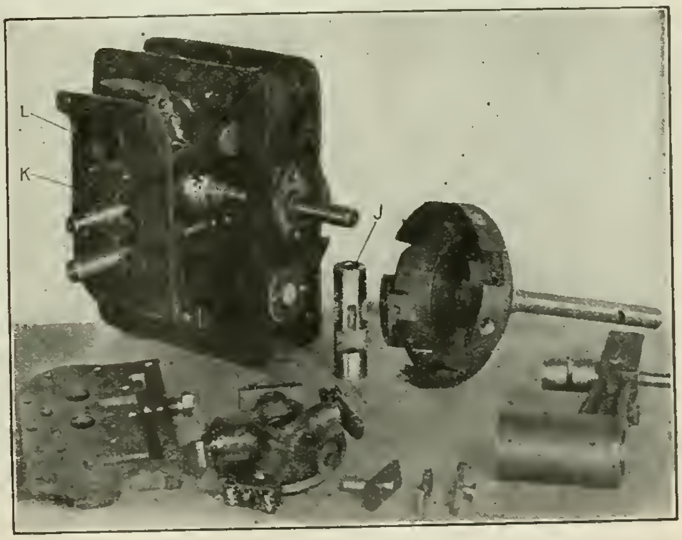

Fig. 7 Lower Part of QC Control Pump

60 deg. in either direction of this travel the effect is to change gradually the stroke of the variable-delivery pump, Fig. 6, thereby pumping more or less oil and moving the piston in the hydraulic cylinder shown in Fig. 5 either to the right or left very accurately, and faster or slower as the operator desires.

When the handle, Fig. 5, is turned 90 deg. either to the right or left to the extreme position, the distributing valve J, revolving in a ported sleeve L, Fig. 7, cuts out the variable-delivery pump from the main pipes M and N, Fig. 5, and connects the large gear pump K, Fig. 7, to these mains, thus driving the piston to the right or left with a very much faster movement. This serves to give a rapid traverse to a lathe carriage or boring-mill ram which may

be operated by this feed; or, in other cases, to the ram of a hydraulic press.

In a preceding paragraph the Oilgear hydraulic transmission was described as a combined unit in a case containing both pump and motor. Also the Oilgear control pump has been described, as made in a separate casing, for operating detached direct-acting pushing cylinders. It can also be used to operate detached rotary motors, such as the one shown disassembled in Fig. 8, which is adapted to drive the feed motions of machine tools, etc. Note the few and simple working parts, all made by ordinary machine-shop processes.

Machine-Tool Feed Applications

The principal elements are the QC control pump, shown in Figs.

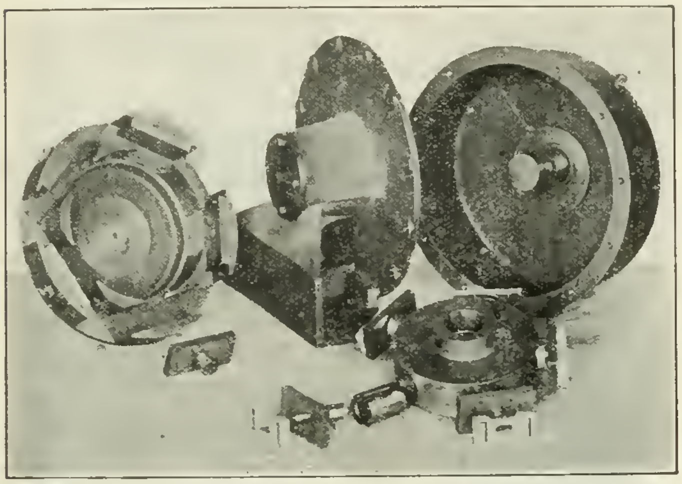

Fig. 8 Disassembled View of Detached Rotary Motor Controlled by Oilgear Hydraulic Transmission

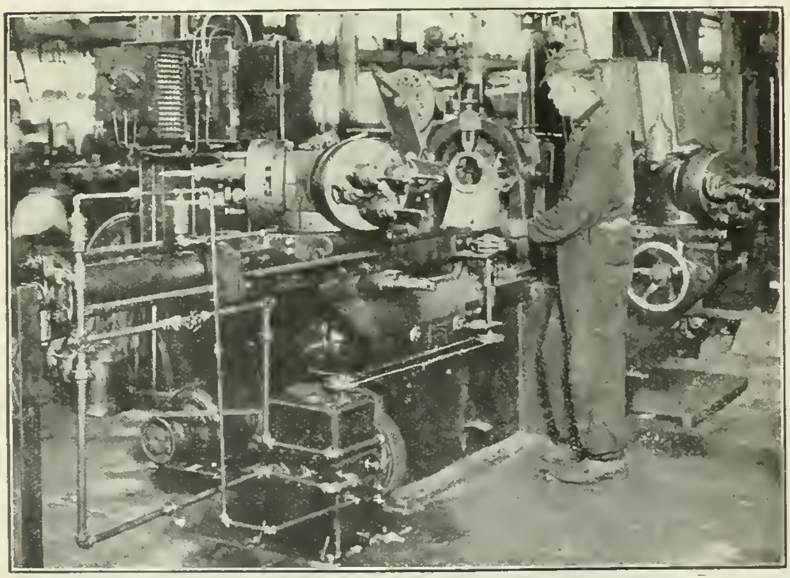

Fig. 9 Special Turret Machine Equipped with Hydraulic Feed

5 to 7, inclusive, connected to a feeding motor for driving a machine-tool carriage or ram, either a direct-acting pushing cylinder as shown in Fig. 5 or a rotary motor as shown in Fig. 8.

In either case the motor is located with reference to the feed mechanism to be driven. The direct-acting feeding cylinder is always to be preferred when it can be used, because of its well-nigh perfect steadiness of operation and the great range of feeding and rapid traverse speeds which can be satisfactorily obtained. For instance, a 4-in. piston may be driven by the variable-stroke pump of Fig. 6 at feeds of $^3/_8$ in. per min. or less, while the rapid-traverse pump (K, Fig. 7) will move the piston at 14 or 15 ft. per min.—a speed ratio of about 450 to 1.

Assuming that a rotary feeding motor can be driven at 1000 r.p.m. for rapid traverse movements, the same speed ratio would require it to turn steadily at $2^1/_4$ r.p.m. when pulling a heavy feeding cut. This range is more than such a motor will satisfactorily handle. In addition, the efficiency of the direct-acting cylinder is much greater, and mechanism is saved.

The application of Oilgear feed has so far been carried out only on already existing machine tools, but several feed installations have been in continuous operation on high-production work for periods of from one to two years, and in no case has there been the slightest wear of the plungers or other working parts.

Fig. 9 shows the application to a special turret machine producing gas-engine beds.

Hydraulic-Press Applications

While the above-described control pump was primarily designed for a machine-tool feed, its properties have proved highly desirable in hydraulic-press work. Such a press, of 25 tons capacity, is shown in Fig. 10. It may be driven from any constant-speed source of power, such as lineshaft or constant-speed motor. Rapid

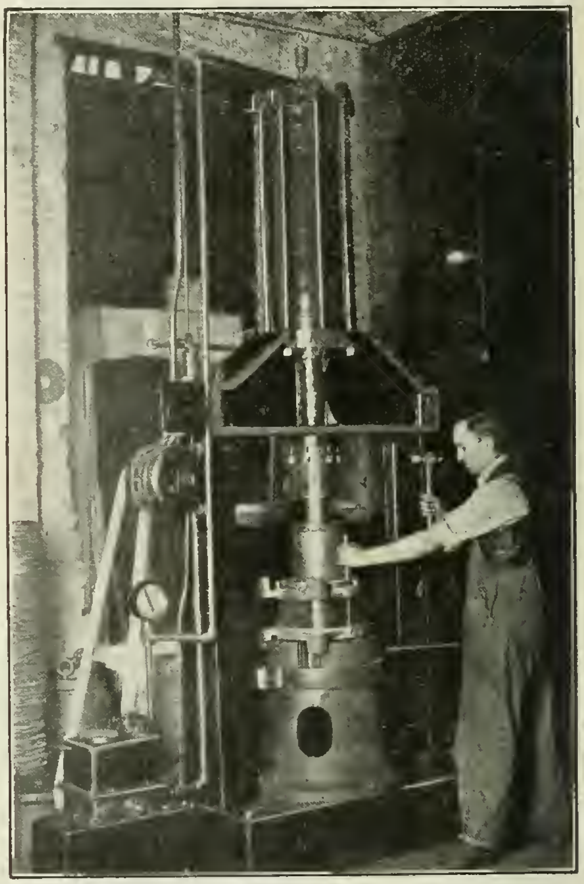

Fig. 10 Hydraulic Press Operated by Oilgear Pump

traverse of the ram is furnished, at a speed of about 40 in. per min. downward and 60 in. per min. upward. While pressing, any speed of the ram up to about 7 in. per min. is available, and the control is so delicate that when the ram is absolutely stalled against a shoulder the pressure gage can be maintained at any desired point. Many other presses driven by Oilgear pumps and having similar operating characteristics are in use.

Broaching. An important application of the direct-acting cylinder is the ordinary broaching process. A horizontal hydraulic broaching machine shown in the complete paper is driven by a 10–15 hp. Oilgear pump. The pulling cylinder is 6 in. in bore, and is double-acting. The piston rod is attached directly to the sliding head which pulls the broach. The reversing tappets are engaged by the sliding crosshead at either end of its stroke as in a planer, and are connected to the pilot valve of the hydraulic reverse gear in the Oilgear pump. The connection to the pilot valve is from a vertical rockshaft whose angle of swing is limited by two adjusting screws, thus controlling the stroke of the pump separately during the pulling and return strokes of the broaching machine and permitting any desired speed up to a maximum of 360 in. (30 ft.) per min.

In the ordinary method of pulling the broaches by screws the usual speed is less than 5 ft. per min., and the hydraulic broaching machine therefore gives a great increase of output, probably averaging 100 per cent. The comparison between the screw and the hydraulic broaching methods may be approximately given by the statement that on the average one hydraulic machine and operator will replace two screw machines and two operators and require about the same amount of power.

Vertical Push-Broaching Presses. The vertical semi-automatic manufacturing press is a further illustration of the adaptability of hydraulic drive to produce machine tools exactly adapted for the work in hand. This press is equipped with an automatic stroke-control gear and is driven by a 5-hp. Oilgear variable-stroke pump known as the Type W. The length of stroke, and hence the speed of the ram, is set by the location of the adjustable tappets. The typical working cycle consists of a downward rapid-traverse stroke at any desired speed through any desired distance, followed by a working stroke at a different speed through any additional distance, automatically reversing and returning to the top position at the completion of the stroke. The ram may be set either for full stroke or for as short a stroke as will be sufficient for the work in hand, and this stroke may be taken near the upper position of the ram or at any other point within its total range. If the entire downward stroke is a working stroke, the rapid approach stroke may be omitted, the entire stroke being set at the required working speed.

Straightening Presses. Equipped in this way this press is available for various vertical broaching and forcing operations. When desired the press may be operated by the QC control pump shown in Fig. 5 and used as a sensitive straightening press. When so equipped, the operator can move the ram by thousandths of an inch if desired, and apply pressure accurately by the pressure gage.

Hydraulic Riveting. A third and even more striking application of such a press is its use as a hydraulic riveter. In this case it is equipped with a pump known as the Type WE, which differs from the Type W only in the method of controlling the stroke. The Type WE pump, is so arranged as to always pump a maximum quantity of oil when the pressure is below a certain point, say, 900 lb. per sq. in. As the pressure rises the pump automatically reduces its rate of delivery until at a predetermined maximum of, say, 1000 lb. per sq. in. the delivery ceases altogether except for the small quantity required to maintain the maximum pressure in the delivery pipe.

When this kind of a control is used the pump is connected to the riveter through a four-way piston valve. The operator handles the press or riveter by operating the piston valve and the pump functions exactly like an accumulator, except that the oil pump only develops sufficient pressure at any instant to overcome the actual resistance of the ram. When the ram is stalled against a rivet or other dead stop the power consumption ceases and the pump runs idle except with sufficient delivery to maintain the pressure.

Such a plant in effect is a portable accumulator plant operating at an overall efficiency of 85 per cent or more, and adapted to be driven from any convenient source of power such as a lineshaft or small electric motor. It requires but from one-eighth to one-sixth the power needed to operate an air riveter, and its use will frequently avoid increasing air-compressor capacity.

Rotary Machine-Tool Drive

The most obvious field in the machine shop for the variable-speed hydraulic transmission is in the main drives of the machine tools themselves. On the other hand, it is the most difficult part of the field to develop, because of the required changes in designs and patterns, but still more because of the high state of development attained by the direct-current electric motor on variable-speed work. Nevertheless, the hydraulic variable-speed drive has several important advantages even over the best electric variable-speed drive, including the outstanding advantages of offering a means of obtaining a perfect speed variation from an alternating-current motor. These may be stated as follows:

a More perfect control of speed
b No coasting when the power is shut off
c No peak loads drawn from the line, and no heating of the hydraulic drive
d Low maintenance and minimum of attention required.

In equipping the average machine tool with hydraulic drive, some saving will be obtained from the omission of a number of gear changes, etc., now required, and a further saving from the fact that all the machines of a certain kind and size will be identical, no matter what the source of power used to drive them. That is, a lathe headstock equipped for hydraulic drive would have a single receiving pulley or shaft to be driven at, say, 600 or 800 r.p.m. It might be driven either from a lineshaft, from an alternating-current motor, from a direct-current motor, or from a gas engine. If such a machine tool came on the second-hand market it would be equally available for installation anywhere.

The mechanism and advantages of hydraulic feed have already been touched upon. Its introduction into new machine tools will be somewhat modified if it is carried out in connection with the use of hydraulic drive for the same tools. In any case the use of the hydraulic method on any machine tool opens the way for the use of hydraulically operated friction clutches to effect gear changes, and also for the replacement of the ordinary air chuck by hydraulically operated chucks. This has already been done experimentally and with complete success. The hydraulic chuck has advantages over the air chuck in consuming much less power, having no tendency to dry out the cup leathers and thus fail to operate, and in moving only sufficiently to release and grip the work instead of making the entire stroke whenever operated.

All of the applications described in the preceding paragraphs have been actually made, and most of them have been in use a sufficient length of time to prove that they are successful practically. Many important fields are not yet touched, although the properties of the Oilgear mechanism seem perfectly adapted to their requirements. Among these are planer drive and other reciprocating movements, cranes and hoists, and elevators.

Discussion

In opening the discussion, J. J. Crain[1] said that the concern with which he was connected had been manufacturing hydraulic transmissions of the same general nature as the one described by the author for about 15 years, and had built about 2000 of them, most of which had gone to the United States Navy, where they were used for turning turrets, elevating guns, hoisting ammunition, etc. All of the present capital ships used this device exclusively for these purposes. The author was very modest in his claims of the performance of this type of apparatus. Before hydraulic transmissions were used in the Navy, most of the high-grade control was effected by the Ward-Leonard system and while this gave very fine control, it was not comparable to what could be obtained from a variable-stroke pump.

His company's associates in England had built about the same number of machines, but had gone more exclusively into commercial work. The real problem in wide commercial application was the financial one. It was an expensive machine. It had to be built accurately and of high-grade material, and to convince a man to pay for it it was necessary to show him that it would produce annual savings which would warrant the investment.

The author seemed to have attacked the most difficult part of the problem first, and with no little success. The control given was without question practically perfect and there was practically no discussion on that point; rather, it was what price could the man who used it afford to pay?

The noise increased with the larger units, that being one of the limitations to the size that could be employed.

Mr. Crain said that he had not found very much difference in efficiency between the large units and the small units, the efficiency lying between 82 and 85 per cent at full speed and full power.

Charles M. Manly,[2] referring to an efficiency curve given in the complete paper, said that it was a curve of efficiency at constant torque and not at constant horsepower. In tests which he had made and presented to the Society[3] in 1911, the efficiency at constant horsepower had been shown to be greater than the effi-

(*Continued on page 245*)

[1] Manager, Waterbury Tool Co., Waterbury, Conn. Mem. A.S.M.E.
[2] Manly & Veal, Consulting Engineers, New York City. Mem. A.S.M.E.
[3] Variable-Speed Power Transmission, George H. Barrus and C. M. Manly, Trans. A.S.M.E., vol. 33, p. 851.

Safety Engineering in the Compression of Gases

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The purpose of this paper is to outline a few of the chief hazards that are associated with the compression of some of the gases in common use in industry. Among the gases considered are air, oxygen, nitrogen, argon, carbon dioxide, hydrogen, acetylene, ammonia, and chlorine. The preparation, utilization, storage, or transportation of the gases, except when some of these items may happen to have an important bearing upon the actual operation of compression, are not discussed. As to the mechanical strength of the apparatus that is used to effect the compression, the paper deals only with the things that are likely to happen even when the apparatus itself is strong enough to withstand the stresses that are thrown upon it in the course of its normal operation.

COMPRESSED air, the first of the gases to be considered, is used for many different purposes and at many different pressures, but so far as safety is concerned it is sufficient to distinguish two main problems. First, we have to deal with cases in which the ultimate pressure desired does not exceed, say, 200 lb. per sq. in.; and second, the special case in which the compression must be pushed to perhaps 3000 lb. per sq. in. for the production of liquid air.

When the ultimate pressure is not greater than 75 lb., the compression is usually effected in a single operation; but it would seem better to adopt two-stage compression for pressures approaching or exceeding this limit. Three stages, at least, should be used for pressures in the neighborhood of 1000 lb., and to push the pressure from this point up to 3000 lb. a fourth stage or operation should be employed. It is advisable to use long-stroke compressors, with low piston speed, not only to avoid unnecessarily high temperatures, but also because less lubrication is needed.

Every now and then there is an explosion in connection with an air compressor, and the results are sometimes quite serious. Most of these explosions are probably associated more or less directly with the lubrication of the compressor cylinders, and with inefficient cooling of the air that is undergoing compression. In an ordinary compressor the temperature of the air rises considerably during the compression stroke, and it is of the utmost importance to keep this rise of temperature within reasonable bounds. A good deal can be accomplished in this direction by surrounding the cylinders with effective water jackets. The cooling water in these jackets should circulate actively and copiously, and thermometers should be provided to show the temperature at which the water is entering and leaving. To guard against stoppage of the flow of cooling water from any cause, it is also important to provide some positive means for showing that the circulation is free and plentiful at all times. It is advisable, for example, to have the discharge from each jacket located where it is plainly visible to the men working about the room.

It is not sufficient, however, to provide the compressor cylinders with water jackets. The air should be passed through a special cooler immediately after leaving the compressor and its temperature brought down near that of the surrounding atmosphere as quickly as practicable. Moreover, if the compression is effected in two or more stages, an intercooler between each stage and the next one should be provided, so that every cylinder will be supplied with air at a moderate and reasonable initial temperature. The use of efficient cooling devices tends not only to insure safety but also to lessen the cost of compression, because cooling reduces the pressure as well as the temperature.

In compressing air to moderate pressures the cylinders are lubricated with oil. Oil may also be used in the first stages of high-compression apparatus, though water is preferable for the final stages. The composition and physical characteristics of the oil should be carefully considered.

As a general rule, too much oil is used in lubricating the cylinders of air compressors. It takes considerable experience to determine just the right amount, and what is right with one machine or one grade of oil may not be right with another. In a general way, however, it is safe to say that the lubrication is ample if the cylinder walls are always coated with a slight film of oil. It is often assumed that the explosions that sometimes occur in connection with air compressors are due to the ignition of oil vapor or of oily mist. It would be hard to justify this theory. Whenever a compressor cylinder discharges the air that it contains, the oily vapor or spray that is present is discharged at the same time, and it is hard to see how a quantity sufficient to produce a serious explosion could accumulate. Moreover there are comparatively few explosions in which the initial break is in the compressor cylinder. More commonly the first rupture occurs in the discharge pipe or the receiver, and trouble at these points can be minimized, and perhaps entirely avoided, by (1) quick and efficient cooling of the air, (2) thorough drainage of the oil that tends to collect in the piping and receiver, and (3) careful attention to the discharge valves on the compression apparatus. Considerable quantities of oil are likely to accumulate in the discharge pipe and the receiver, and if either of these bursts, a large amount of hot oily spray is likely to be discharged into the air, and this may take fire either spontaneously or from some external source, with a bad oil-vapor explosion as the result. Suitable traps and drains must be provided to prevent the accumulation of the oil, and in this way the oil hazard can be largely or wholly removed.

If the exhaust valves of the compression apparatus are leaky, then upon the return stroke more or less of the compressed and heated air will find its way back into the cylinder, so that the temperature of the air in the cylinder upon the next compression stroke will reach a much higher point than the designer of the apparatus intended. Carbonaceous deposits, produced by the carbonization of the lubricating oil, often collect in considerable quantity in and around the exhaust valves, and these may sometimes take fire, or they may prevent the valves from closing tightly. Exhaust valves should be carefully watched for such deposits, and should be kept as clean and tight as possible.

Oxygen

Oxygen is compressed and shipped in vast quantities and is used in the greatest imaginable variety of ways. Before subjecting it to compression it is essential to know that the oxygen is pure, and especially to know that it is not contaminated with any other substance with which it could combine, either during compression or in the course of subsequent handling. For example, if it is prepared by the fractional distillation of liquid air, it is important to know that the air that was subjected to liquefaction was free from smoke particles, from organic dust of any kind, and from coal gas, acetylene, and every other substance of an oxidizable nature. If the oxygen was produced by the electrolysis of water, it is equally essential to know that it is not contaminated by hydrogen. It is easy enough to insure purity in all these respects, but the importance of not neglecting the necessary testing, and the purification operations when these prove to be needed, cannot be over emphasized.

In handling compressed oxygen it is supremely important to prevent the gas from coming in contact with oil or grease either during the compression or while the oxygen is being stored, transported, or utilized; and in view of the fact that many exceedingly serious accidents have occurred in consequence of neglecting this principle, the author wishes to emphasize the hazard just as strongly as he can. When a man talks with appropriate earnestness about the danger of allowing compressed oxygen to come in contact with oil, grease, or other combustible organic materials, it is easy for the uninitiated to believe that he is inspired by unreasonable timidity, but this is not the case. Those who have followed the history of oxygen compression are well aware that many accidents have occurred under conditions that thoughtful and experienced men

[1] Director of Technical Research and Safety Publication Work, Travelers Insurance Company and Travelers Indemnity Company. Mem. A.S.M.E.

Presented at a joint session of the American Society of Safety Engineers and the A.S.M.E. Safety Codes Committee at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. All papers are subject to revision.

would not have considered to be at all likely to produce trouble. The use of even a slight trace of oil in the compressor is exceedingly hazardous, not only on account of the danger of immediate combustion, but also because some part of the oil is bound to go over with the compressed gas; this will collect in the tanks or cylinders used for storage purposes, and sooner or later serious results will surely follow. It is probably safe to say that most of the accidents that have occurred in connection with compressed oxygen have been due to lack of appreciation of the importance of this thing. The trouble is not confined, of course, to the mere combustion of the oil itself. The metal parts of the apparatus will burn freely as soon as they become sufficiently heated by the ignition of the oil or grease, and the consequences may transcend imagination.

The only absolutely safe thing to use for the lubrication of an oxygen-compressor cylinder is *pure water*, which should be introduced into the suction pipe in the form of a visible spray. Under special conditions it may happen that pure water is not sufficient, and in a case of this kind it may be permissible to dissolve a little soap in it; but soap should not be used when water will suffice, and it should *never* be used without first proving, by actual analysis, that the particular supply to be dissolved contains no uncombined (or unsaponified) oil or grease. The packings used on the compressor must also be entirely free from oil, grease, or graphite. Packings made for this express purpose should always be employed.

The compression of oxygen is often, and perhaps usually, carried up to about 2000 lb. per sq. in., and it should be effected in not less than three stages. In speaking of the compression of air, the importance of prompt and effective *cooling* has been emphasized, and much greater attention should be paid to this point when compressing oxygen. The pump cylinders should be water-jacketed, the circulation of water should be positive and abundant, and the apparatus should be so designed that cessation or diminution of the flow of jacket water cannot escape immediate notice. The gas should also be passed through effective intercoolers between each compression stage and the one next following; and *immediately* after leaving the last cylinder of the compressor it must be passed through a final cooler, and brought down to the temperature of the surrounding atmosphere.

It is exceedingly unwise to introduce oxygen into receivers of any kind, unless these receivers are known to be perfectly clean internally and wholly free from oil, grease, and other combustible substances. The author would like to see some kind of a regulation established forbidding every oxygen manufacturer to fill any tanks other than his own. This principle is already followed, it is believed, by some and perhaps all of the larger manufacturers, but unfortunately it is not followed by everybody. Moreover, oxygen should never be compressed into containers that have been used for other gases. When a cylinder or tank has been previously used for holding compressed gases other than oxygen, there is likely to be an accumulation of oil upon its inner surface, because oil may have been used for cylinder lubrication in connection with the compression of these other gases, and it is hard to remove such oil thoroughly enough to make the tank safe for oxygen.

Nitrogen

Nitrogen gas has a far narrower range of application in the arts than oxygen, yet it is compressed and shipped to a certain extent. This gas was used during the war in the recoil cylinders of certain types of guns, and it has also been used to a limited extent for blanketing combustible liquids and for supplying a neutral atmosphere for other purposes, where the presence of a gas with active chemical properties would be objectionable. At the present time compressed nitrogen is supplied mainly, it is believed, for filling incandescent electric lamps, and in connection with the manufacture of automobile tires.

Nitrogen forms four-fifths of the bulk of the atmosphere, and as it is nearly inert in its elemental form the precautions that are recommended in connection with the compression of air are also adequate when compressing nitrogen. It should be noted, however, that the nitrogen that is used for filling electric-lamp bulbs must be free from hydrocarbons, and this means that when the gas is to be employed for this purpose it is not permissible to use oil for lubricating the compressor cylinders. Water should be used instead. For certain reasons, in fact, it is best to avoid oil altogether and to lubricate with water in all cases. This does not mean, however, that there is any danger of direct chemical action between the oil and the nitrogen.

Nitrogen is usually compressed to about 2000 lb. per sq. in., and the compression should be performed in three stages.

Argon

Argon, like helium and neon, has no chemical properties whatsoever. It forms no compounds and is absolutely inert under all circumstances. Hence it cannot produce fires or explosions. Moreover, it is not poisonous. It is obtained from liquid air, however, and when first separated from the air it is mingled with a large proportion of oxygen—the mixture usually containing about 65 per cent of oxygen and 35 of argon. When it is handled in this state it must therefore be treated like oxygen; but after it has been freed from the admixed oxygen it may be compressed under the same conditions as nitrogen. For shipment it is usually compressed to a pressure of 1800 or 2000 lb. per sq. in., in three stages.

Carbon Dioxide

This gas is compressed in large quantities and is used for the most varied purposes. As is well known, it will neither burn nor support combustion, and the author does not recall any chemical dangers which are likely to be encountered in its compression. It is not especially poisonous, but when a considerable quantity of it is mixed with the air that the workmen have to breathe, it replaces the life-giving oxygen to a corresponding extent, and this may mean that the air is not fit for respiration. The effects of carbon dioxide in this way are sometimes very insidious, especially as the pure gas is without odor or color; and it is therefore evident that special care should be taken to provide free and copious ventilation at all times in buildings in which carbon dioxide may escape, by leakage or otherwise.

Hydrogen

In connection with hydrogen and most of the other combustible gases (such as propane), the chief danger associated with compression probably consists in the likelihood of fire or explosion in case of leakage or of contamination with oxygen. If the hydrogen is prepared by the electrolysis of water, there is always a possibility that oxygen may be present in it in small amounts, and the gas should be carefully tested, either at short intervals or preferably by some continuous process, to make sure that the oxygen content is always well below 5 per cent. Small amounts of oxygen can be removed by passing the gas over palladium pumice, which causes the oxygen to combine in a quiet way with an equivalent quantity of hydrogen.

The danger of admixture with air or oxygen is not in any way restricted to hydrogen prepared by the electrolytic process. Air may leak into the suction pipe leading to the compressor, whatever the source of the hydrogen; and this, in fact, is one of the hazards that must be watched most carefully in handling this gas. The suction line may be fitted with test cocks or drainage valves, and when this is the case it is exceedingly important to keep them closed except when they are opened for legitimate purposes and at proper times. It is believed, moreover, that all such cocks and valves should be kept locked, and that the keys should be in the keeping of some designated, responsible man. To guard further against trouble from this source and from accidental leakage, the whole operation should be conducted so that there will be a positive pressure in the suction line *at all times*. Care should also be taken that the gasometer does not stick and that its seams are kept absolutely tight.

It is important to consider the possibility of leakage outward as well as inward. Hydrogen is usually compressed to a pressure of 1800 or 2000 lb. per sq. in., and at high pressures a good deal of gas will escape through a small hole in a short time. If hydrogen gets out into the room and is allowed to collect there, a serious explosion is likely to result. Every discoverable source of ignition should be carefully considered and safeguarded. Rigorous measures should be taken to prevent the men from smoking or using matches or other sources of open flame. The artificial lighting should be provided by incandescent electric lamps enclosed in

vapor-proof globes, and it is safest to mount these lamps outside of the windows, locating them so that they shine through the window glass into the interior. All electric wires should be run in closed conduits, and the fuses should invariably be outside of the region of possible danger. This applies also to switches, unless they are of a type which cannot produce an arc or flame. No electric motors should be used in rooms where hydrogen, propane, or any other combustible gas may escape in quantity, unless these motors are specially designed for this particular application, or else thoroughly ventilated by fresh, pure air from the outside of the building. And these various precautions should be observed not only where the hydrogen is compressed, but also wherever it is stored—either in gasometers or in cylinders. Finally, it is exceedingly important to provide abundant ventilation at all times to lessen the chance of fire or explosion in case the other precautions prove inadequate.

Left-handed threads are extensively used for fittings that are to be employed in connection with hydrogen, the purpose being to prevent the accidental connection of hydrogen lines or cylinders with pipe lines conveying other gases, and especially with those containing air or oxygen. It is to be regretted that in many plants the purpose of the left-handed thread is deliberately defeated by making use of devices known as "adapters." These are in effect right-and-left couplings, which are provided for the express purpose of making it possible to attach a cylinder with a left-handed thread to a pipe line having a right-handed thread.

Acetylene

No person should ever undertake to compress acetylene unless he fully understands the properties of the gas and knows exactly what it is permissible to do and what he must carefully avoid doing. This is not meant to imply that the compression of acetylene is a dangerous operation when it is performed under the direction of a properly qualified man, but is intended as a special note of warning to those who are tempted to compress the gas without first understanding its properties. Acetylene is an endothermic compound, and this formidable word has frightened a great many persons who do not understand its exact significance. It merely means that heat is absorbed (instead of emitted) when acetylene is formed from its constituent elements. Now it is well known that substances of this kind are likely to be more or less unstable under certain conditions, and acetylene is no exception to the rule; but the conditions under which the instability exists are well known, and it is only the man who does not understand them, or who is pleased to ignore them, who gets into trouble.

In compressing acetylene it is important to keep the temperature of the gas as low as practicable at all times. Expressed in more definite language, this means that the compression must be effected by a pump moving with a very low piston speed, and that it must be performed in not less than three stages. It also means that the pump cylinders should be kept as cool as practicable by a plentiful supply of water drawn from the coolest available source. The author cannot state any definite temperature at which the gas may become instable during the act of compression, and in fact it is doubted if anyone knows what that temperature might be. The only thing that we can say is, that if the operation is conducted as here described, there is apparently no danger from instability. It certainly is not safe, however, to *store* acetylene in otherwise empty cylinders, at the pressure at which the compressor pumps deliver it. There appears to be a time element involved here, and it is probable that a certain amount of polymerization gradually occurs in strongly compressed acetylene (except when it is stored in special receptacles containing suitable porous material charged with liquid acetone), so that in the course of time small quantities of other more sensitive substances are formed, which serve to lessen the stability. At all events, we know that acetylene should not be stored in an otherwise empty tank at a pressure of more than 15 lb. per sq. in. greater than the normal pressure of the atmosphere, and yet we know that explosions in the compression pumps, and in the delivery pipes leading from them, are exceedingly rare if the compression is effected as here described. In fact, the author knows of only one case of the sort, and this was precipitated by the breakage of a steel valve spring, which quite possibly struck a spark and thereby caused the development of a high temperature within the tiny space filled by the spark itself.

Oil may be used for lubricating the cylinders of acetylene-compressing pumps, but it should afterward be removed by passing the compressed gas through suitable separators as it leaves the compressor. And immediately upon leaving the oil separator the acetylene should be passed into the storage cylinders, which, as previously stated, must be filled with a special porous, solid material thoroughly impregnated by liquid acetone, which dissolves the acetylene and holds it safely in solution.

It should not be necessary to issue a warning against mixing other gases with acetylene in the storage tanks, or using acetylene storage cylinders for any purpose whatsoever, except for holding pure, unmixed acetylene (in addition to the safety filling).

Ethyl Chloride, Methyl Chloride, and Propane

These gases are used to some extent as refrigerating agents, but it does not appear desirable to discuss their compression in any detail. They are all inflammable, and hence must be handled with due regard to the possibility of fire and explosion. Propane (like butane) does not require lubrication in the compressor cylinder, because the substance itself affords sufficient lubrication. It is necessary, however, to lubricate the stuffing box of the compressor. There has been some difficulty in connection with the lubrication of cylinders in which the chlorides of ethyl and methyl are compressed. Castor oil has been used, but it is not very satisfactory. Glycerine is said to be much better, though still far from ideal. It is said that a new lubricant, consisting of ethylene and propylene glycol mixed with deflocculated graphite, and specially adapted to ethyl and methyl chlorides, and to propane, is now available.

In handling these and all other inflammable gases the various special precautions mentioned in connection with hydrogen should also be observed.

Ammonia

Liquefied ammonia is used in immense quantities in connection with refrigerating machinery, and although it perhaps cannot be called a poisonous gas in the narrow sense of the term, it is easily capable of producing unconsciousness and death when it is present in the air in any considerable amount. Similar remarks apply to sulphur dioxide gas, which is also used in refrigerating machinery as well as in various other applications. Both of these gases are freely soluble in water, and it is recommended that in all rooms in which they are handled an overhead sprinkling system be provided that is capable of discharging large volumes of water into the room in case of the accidental liberation of excessive quantities of either gas. A considerable part of the liberated gas would be absorbed by the down-rushing water, and even though the air might not be rendered respirable in this way, something would surely be gained in the way of checking the spread of the gas to other rooms. It is certainly important to provide free and abundant ventilation in and adequate means for quick exit from any room in which either gas may suddenly be liberated in quantity. These simple and evident precautions are often wholly disregarded in laying out plants in which ammonia or sulphur dioxide are handled or used.

Ammonia gas is usually pronounced incombustible and incapable of being exploded when mixed with atmospheric air, but research and experience have shown that this is not altogether true. A mixture of ammonia gas and air can be exploded if it contains from 16 to 27 per cent of ammonia, and some of the explosions that have occurred in our big refrigerating plants subsequent to the liberation of considerable quantities of ammonia may possibly have been due to the ignition of mixtures of this kind by means of the arc lamps which have in most cases been in use in rooms where these accidents have occurred.

In compressing ammonia another source of danger must be carefully considered. If the ammonia gas that is undergoing compression is allowed to become unduly hot, the ammonia that comes away from the compressor will contain a notable quantity of combustible gas that is distinctly different from ammonia. This may come in some measure from the decomposition of the oil that is used in lubricating the compressor cylinder, but it also contains free hydrogen, which appears to be produced by the actual dissociation (or breaking up) of the ammonia into its component gases, nitrogen and hydrogen. We used to think of ammonia as being exceedingly stable and incapable of dissociating in this way

to any sensible extent, but we now know that such is not the case. Dissociation occurs even at moderate temperatures, and it is likely to become quite significant when the temperature is high. To guard against the development of combustible decomposition products from the lubricating oil, it is important to use a special kind of oil which experience has proved to be well adapted to work of this kind; and to keep the dissociation of the ammonia itself within as low a limit as practicable, it is important to keep the gas as cool as possible by methods already outlined in connection with other gases. Finally, to guard against vapor explosions in case ammonia gas should escape into the air in considerable quantity, it is important to take the same precautions against ignition sources that have been suggested in connection with hydrogen.

Chlorine

Liquid chlorine is now shipped in vast quantities, for use in connection with bleaching, and for many other purposes. It has been greatly feared by the general public ever since it was used as a military gas in the war, but in time of peace this fear is hardly justifiable. Chlorine is exceedingly irritating, and it can produce unconsciousness and even death if inhaled in any considerable quantity. It has been well described as an "honest gas," however, the phrase meaning that it has no treacherous qualities. We always know exactly what it will do. In a manufacturing plant, or in a plant in which chlorine is compressed, immediate relief can be had, in case of leakage, by merely leaning out of an open window or going out of the room. It is not desired to underrate the dangers associated with handling liquid chlorine, yet it is only fair to say that they have been largely exaggerated. If a cylinder or a tank containing liquid chlorine bursts or springs a leak, for example, the evaporation that takes place rapidly chills the liquid still remaining in the tank, so that the evolution of gas is quickly and automatically checked, though not wholly stopped. Abundant ventilation is important in a chlorine plant and special attention should be given to the exits, so that if the gas becomes accidentally liberated in considerable quantity the men can pass out into the open air as quickly and directly as possible.

Chlorine must be carefully dried before compression, because if it is moist it will corrode the pump, piping, and tanks. Perfectly dry chlorine, on the other hand, has practically no action upon iron. The drying is effected by passing the gas through towers filled with pumice wet with concentrated sulphuric acid. In liquefying the gas by means of a compression pump the main difficulty to be overcome is keeping the piston gastight in the compression cylinder. A special form of packing is required for this purpose, and it should be designed and installed by some person who understands the necessities thoroughly. In one compression plant visited by the author there are seven sealing rings on the piston—six soft and hard packings of special chlorine-resisting material being used, while the middle space is filled with strong sulphuric acid which not only completes the seal but also serves to lubricate the cylinder. The pressure required in chlorine tanks is not high, as the vapor pressure of liquid chlorine is only about 120 lb. per sq. in., at 70 deg. fahr.; and even when a chlorine tank has been left standing in the sun for a considerable time, the pressure will hardly ever creep up as high as 160 lb. per sq. in. In liquefying this gas the compression is therefore performed in one operation. Tanks and other apparatus used in handling or storing chlorine must be clean and free from all other substances—solid, liquid, or gaseous—with which the chlorine might combine.

In conclusion, there is one general suggestion relating to safety-valves which applies to all gases. Some engineers discourage the use of safety valves on gas-compressing apparatus, partly because the escape of gas through them is a source of waste, and partly because it creates a special hazard, when the gases are toxic or inflammable. But it is not necessary to liberate the escaping gas at or near the work place, and it can often be discharged where it will not constitute a hazard to property. Hence this objection is not altogether well founded. In fact, relief valves should be provided in all cases, and the discharge problem should be considered on its own merits in each individual plant. It is often, and perhaps usually, practicable to have the discharge delivered back into the piping system on the low-pressure side of the compressor, so that there is no economic loss, and no hazard to the men nor to property.

Discussion of Hydraulic-Transmission

(Continued from page 241)

ciency at constant torque, so that the author's curve would be better at constant horsepower. This was a condition which was of great interest in many applications where it was possible to get increased torque with decreased speed and full horsepower within a reasonable range.

Of course a full horsepower output could not be obtained throughout an infinite speed range. If one ordered a machine for a 10 to 1 range at a constant capacity and needed only a 5 to 1 range, he would have to buy a machine of twice the capacity actually necessary.

In closing the discussion the author said that Mr. Manly had raised an important question in his comment on the increased efficiency shown in his tests at constant horsepower. He did not know whether a similar condition existed in the Oilgear, as it depended on the relative values of the different components of the total loss, such as mechanical and hydraulic friction.

Of greater practical importance was the method of obtaining the constant horsepower output. If this was done by varying the pump stroke, the working pressure would increase as the pump stroke was reduced. This amounted to underrating the machine in order to call it a constant-horsepower machine. If it was to operate at half-stroke with 1000 lb. per sq. in. pressure and at full stroke with 500 lb. per sq. in. to give constant horsepower, it might as well carry doubled rating at full stroke, unless limited by bearing pressures or speeds, or by overheating.

Regarding Mr. Crain's remarks on the subject of costly construction, the author believed that the simple plane and cylindrical parts used in the Oilgear would lead to a reduction of cost. This prospect had led him to believe that the machine-tool field and similar fields should be considered open for hydraulic-transmission methods.

The variable-stroke oil pump as a power transmitter had the following outstanding characteristics:

- *a* Complete speed control of the driven motor
- *b* Transmission of maximum torques to the driven motor without requiring large power input
- *c* Automatic regulation of power input at all speeds to the amount actually required to deliver the power output
- *d* Perfect lubrication and consequent extreme durability
- *e* Negligible idling load
- *f* Ability to operate as a disengaging clutch by setting the pump at zero stroke.

No other power transmitter combined these properties, and very few power transmitters had any of them. The direct-current electric motor, however, had been highly developed as a variable-speed drive, and had a large field appropriate to it in which the hydraulic drive would not compete.

It was very important to get a clear idea of the essential distinction between hydraulic variable-speed drive as herein presented and the ordinary types of hydraulic machinery. Every Oilgear transmission comprised a pump, a motor, and an oil circuit connecting them. The volume of the liquid flow and hence the speed of the motor was determined only by the pump displacement. The pressure of the working fluid was determined only by the resistance encountered by the motor, and rose and fell with the load to be driven. There were no throttle valves and no reduction of pressure in the working liquid except when it passed through the motor. Then the pressure instantly fell to exhaust pressure, the drop being just sufficient to compel the motor to turn against the mechanical resistance to be overcome, because the high pressure was determined and caused by this same resistance.

The ordinary hydraulic system, including an accumulator, required a maximum pressure to be delivered by the pump whether the work needed this pressure or not, and the surplus was wasted or wiredrawn through the throttle valve between the accumulator and the working machine. This throttle valve controlled the movement of the working ram both as regarded speed and the pressure delivered. That part of the power not needed to drive the working machine at the required speed was lost, and was also used to cut the working parts and destroy the mechanism itself.

Performance Tests of Steel Belts with Compressed-Spruce Pulleys

Particulars Regarding an Investigation of the Performance of Welded and Continuous Steel Belts Running on Compressed-Spruce Pulleys Not Specially Faced

By GARTH L. YOUNG[1] AND GUIDO V. D. MARX[2]

FROM the data available it would appear that the possibility of using thin ribbons of steel in place of leather or composition belting for power transmission was conceived by Eloesser in Germany some fifteen years ago, but that at first various mechanical troubles stood in the way of extensive adoption of the new device. It was not until a few years ago that these troubles were overcome to a sufficient extent, and it is stated that at present close to 1,000,000 hp. is being transmitted by steel-belt drives.

The authors have carried out a series of tests with continuous steel belting and compressed-spruce pulleys. Heretofore the two outstanding difficulties with steel belts have been the impossibility of securing a satisfactory joint and the fact that the pulleys must be specially faced in order not to run metal on metal, which would ultimately, perhaps after a short period of satisfactory operation, give rise to excessive slip and consequent power loss. Because of this the combination of continuous belting and compressed-spruce pulleys would appear to be of particular interest.

Compressed-Spruce Pulleys

The driver and driven pulleys were 20 in. in diameter, 6 in. face,

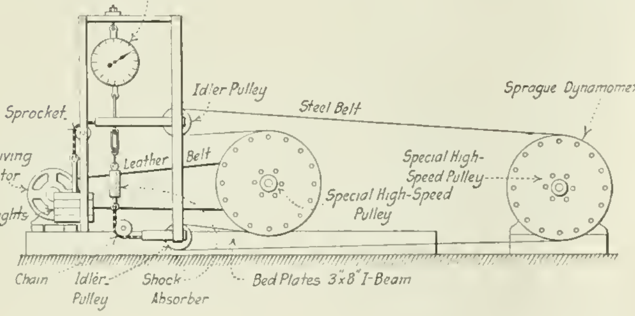

Fig. 1 Diagrammatic Sketch of Steel-Belt Testing Machine

compressed spruce, and the idlers 12 in. in diameter with 4 in. face. According to the manufacturers, "The method used in constructing these pulleys is to lay up $^3/_8$-in. thick lumber in square blocks with the alternate layers at right angles, glueing with Casco casein joint glue to whatever thickness is desired, place in a hydraulic press and compress the block perpendicular to the plane of the layers, clamp and hold for from 48 hours to a week. The clamps are then removed and the block remains compressed with practically no expansion. The block is then bored with a hole that is slightly smaller than the outside of the cast-iron hub. The machined hub is then pressed in by hydraulic pressure and the pulley turned on a mandrel in an engine lathe. The pulleys are then doweled with fir dowels, the set-screw hole (if required) bored and tapped, placed on the mandrel again, and sanded and finished." A block of this material was compressed under a pressure of 4800 tons per sq. ft., or around 68,000 lb. per sq. in. without having it fail by spreading out, and although these pulleys have never been tested to destruction by centrifugal force, it would appear from the foregoing that the wood in tension will carry up to far above ordinary driving speeds.

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Abridgment of a thesis submitted by the authors in June, 1922, to the Department of Mechanical Engineering and Committee on Graduate Study of Leland Stanford Jr. University in partial fulfillment of the requirements for the degree of Engineer.

Belt Material and Joints

The material used for belting in these tests was what is known commercially as clock spring. It is a very high-carbon charcoal steel apparently rolled and ground to size and drawn to a dark blue temper. The belt used was 0.01 in. by 0.75 in. by 35 ft. This material may be obtained in varying widths, thicknesses, and tempers. In the 0.01-in. thickness the widths obtainable are from $^1/_2$ in. to 3 in. in tempers of light straw, dark straw, and dark blue.

First tests made to determine the tensile strength of the belt were unsatisfactory due to the fact that the material was so weakened by the scarf marks in the grips of the testing machine that the belt failed in the jaws at loads of from 225,000 to 250,000 lb. per sq. in. This difficulty was obviated by looping the belt in either grip, thus giving two thicknesses instead of one. The belt then broke cleanly between the grips at a load of 275,000 lb. per sq. in.

The previous work done with belts of this material clearly shows that a silver-soldered lap joint is by far the most satisfactory to use, hence little time was spent on the construction and test of joints of different types. A triple-riveted lap joint was made up and tested, eleven $^3/_{32}$-in. Norway tinned rivets being used. This type of joint was never run on the apparatus as it was clearly far too stiff to stand the reversals of stress over the 12-in. idler pulleys. When tested for tensile strength the rivet heads pulled out and sheared at a load of 108,000 lb. per sq. in., giving an efficiency of 39 per cent.

The silver-soldered lap joint was made as follows: The ends were squared up and scarfed to a razor edge with a file and emery cloth, the length of the scarf being about three-quarters the width of the belt. The ends were then clamped firmly in place and from $^1/_4$ in. to $^3/_8$ in. of $^3/_4$-in. by 1-in. silver solder inserted. A small quantity of borax was used as a flux. Red-hot tongs were then firmly clamped over the joint until the solder melted and flowed evenly. The joint was then allowed to slowly cool, the oxide and surplus solder being polished off.

The joint used in all the test runs, covering a period of at least 50 running hours, was later cut out of the belt and tested for tensile strength in the manner described earlier. The specimen failed at the edge of where the temper had been drawn by the tongs, and not at the joint itself. The breaking load was 153,000 lb. per sq. in., giving an efficiency of nearly 56 per cent. Apparently the joint was so constructed as to be perfectly flexible and the reverse stresses over the 12-in. idlers had not affected its strength to any appreciable degree.

Description of Apparatus Used in the Tests

The apparatus used in these tests amounted essentially to a dynamometer whereby the tensions in the tight and loose sides of the belt could be accurately measured. This was accomplished by using two idlers mounted on swinging frames as shown in Fig. 1. For measuring the slip between the driver and driven pulleys a differential counter was used which was originally built by Helmick for his tests (see Mechanical Engineering, July, 1920, p. 374). The mechanism of the differential counter is such that when the driver and driven shafts rotate equally in opposite directions there is no movement of the ring gear G, Fig. 2. The light chains shown connect the counter to the driver and driven shafts.

Due to the one-to-one ratio of the sprockets and equal diameters of the pulleys there is no motion of the ring gear unless the belt is slipping. When slip occurs the rotation of the ring gear is proportional to the difference in peripheral velocity of the two pulleys. The ratio of the ring gear to its pinion is one to twenty and the ratio of the differential gears is two to one, making the ratio from the wheel shafts to the ring pinion one to ten.

The motion of the ring pinion is transferred to a specially built counter by means of a light chain and sprockets. This counter is engaged and disengaged by an electrically operated dog clutch. The unit wheel of the counter is divided into tenths so that one division of this wheel corresponds to a difference in revolutions of one one-hundredth between the driver and driven pulleys.

The revolutions of the driver pulley are taken with a Veeder counter operating in the same circuit as the differential and direct connected to the differential-wheel shaft.

Test Procedure

As the load on the weight pan and the reading of the dial balance will not give directly the tensions in the belt under test because of the angularity of the belt pull, the apparatus was properly calibrated.

The next problem was to overcome the effect of vibration, which was successfully achieved with certain modifications in the apparatus.

The object of making the tests described herewith was to obtain the relation of the coefficient of friction to the main variables of pressure, driving velocity, slip velocity, and horsepower over a practical driving range. The method followed was to maintain a constant tension in the tight side of the belt and vary the load from the point of little or no slip to a value considered excessive. This was repeated at each tension for all the available driving speeds. It was first desired to check up the work of Hampton, Leh, and Helmick with steel on cork-faced pulleys and see what variations from their results could be ascribed to the use of compressed-spruce pulleys. It was found that the two sets of tests gave results approximating each other quite closely.

The relations found to exist between the coefficient of friction u and the driver velocity V_d, slip velocity V_s, and pressure P showed that the coefficient of friction varied inversely as the 0.533 power of the pressure, inversely as the cube root of the driven velocity, and directly as the 0.174 power of the velocity of slip.

By selecting thirty representative sets of values of the variables a solution was made for the constant K. The average of the thirty gave $K = 32$. The formula in its final form therefore reads—

$$u = \frac{32V_s^{0.174}}{P^{0.533}\,V_d^{0.333}} \quad \ldots\ldots\ldots\ldots\ldots\ldots [1]$$

and while variations will be found in the cases of extreme values of the coefficient, this equation fits very satisfactorily over the main range of values.

As it was desired if possible to find an equation of simpler form which would fairly closely apply, a determination of the constant was made in ten representative cases when the following formula was used:

$$u = \frac{KV_s^{1/8}}{P^{1/2}V_d^{1/3}} \quad \ldots\ldots\ldots\ldots\ldots\ldots [2]$$

It was found that this formula could be applied with a little more variation than the one given above, when the value of $K = 32.91$ was used.

A table was constructed to show the relative efficiencies of the various types of pulleys. The method followed was to go over the data and select, at tensions in the tight side of the belt as nearly equal as possible, readings in which the velocity of slip and driver velocity were also constant. The only variable which now could affect the coefficient of friction and the horsepower transmitted was the self-adjusting value of the tension in the loose side of the belt. The coefficient of friction of steel on compressed spruce and the corresponding horsepower is higher in each case than the values of steel with cork-faced pulleys, the average ratio (horsepowers transmitted) of wood to cork being 1.36.

As regards the relation between horsepower, velocity of slip, and tension in the tight side of the belt, the results obtained by the present investigators check very closely with those of Helmick, but in the relation involving the coefficient of friction, velocity of driver, and velocity of slip, there is considerable variation between the results obtained by the two sets of investigations, the equation derived by the authors being as given above in [1], where u is the coefficient of friction, V_s the velocity of slip, V_d the velocity of driver, and P the pressure in pounds on the pulley face. The difference between the two equations shows the relative influence of the variable factors with the two kinds of pulleys.

The next series of tests dealt with the performance of continuous belting on compressed-spruce pulleys. At the time the belts were needed it was impossible to secure belts of more than 20 to 22 ft. open length, and as the specifications from the manufacturer of the belt required 20-in. diameter pulleys when reverse stress occurred, the apparatus as heretofore used became impractical. An effort was made to devise some apparatus which would give a practical drive for the continuous belt and at the same time admit of some method of accurately determining the tensions. This apparatus is described in the unabridged thesis.

Continuous Steel Belt

The continuous steel belt tested was quite different in physical appearance from the welded belt. In appearance it was bright and highly polished, the edges being slightly rounded to reduce the hazard in handling while running, although it should be borne in mind that the safest plan is to align the apparatus so that adjustment of the running belt is unnecessary. The continuous belt is apparently not tempered to the degree of the clock spring used heretofore, and in consequence must be handled more carefully to prevent giving it permanent twists or sets. No physical tests of the material were made as it was not believed that the knowledge to be gained justified the breaking of one of the belts for this purpose.

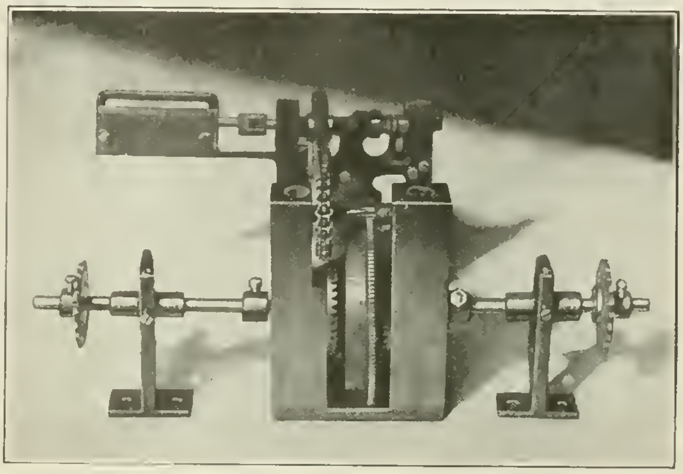

Fig. 2 Differential Counter Used for Measuring the Slip Between the Driver and Driven Pulleys

From tests it was found that the horsepower varies as the 0.78 power of the velocity of the driver, in addition to which the following general relation was obtained:

$$\text{Horsepower} = \frac{1.51\,P^{0.81}V_d^{0.78}}{1000}$$

This formula checks out quite closely with the observed and computed data from which it was taken, with the exception that slight variation occurs at the highest velocities, when the computed value is a little high. The formula has a practical value in determining belt tensions and dimensions knowing the horsepower to be transmitted and the belt speed.

An effort was made to compute the coefficient of friction as a function of various variables in the case of a continuous belt and the values obtained proved to be extremely low, ranging from 0.192 to 0.240 in one series and from 0.198 to 0.257 in another.

The explanation of the extremely low values of u obtained in working out the data in some cases is that the floating pulley allowed the tensions in both sides of the belt to adjust themselves, and naturally at very low horsepowers, values as low as 0.0233 being recorded, the tension in the loose side of the belt became very nearly equal to that in the tight side, with the consequent result that the ratio of (t_1-t_c) to (t_2-t_c) approached unity. The logarithm of this ratio being very small, u approached zero as the limit. At just what point the values of u become reliable is difficult to determine, but it is evident from past experience that values below 0.12 or 0.13 should be disregarded.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

Vibrations in Foundations

By DR. ENG. ERNST SCHMIDT

Description of a method of investigation based on the use of vectors. One of the features of this method is that it employs a so-called "foundation function" which expresses the motion of the foundation for every direction of freedom of oscillation in accordance with the magnitude and phase of the motion at all frequencies.

The development of vibrations in a foundation is dependent on the following elements: First, the force producing the oscillations; second, the inert mass of the machine on the foundation; third, the properties of the foundation itself; and fourth, the action of damping elements.

For theoretical purposes the investigation is limited to periodic processes which are resolved according to Fourier into harmonics, one such harmonic being taken, for example, the basic oscillation. The machine on the foundation may be considered as a rigid unit against which the oscillating masses exert periodically acting forces. The machine is assumed to rest directly or through an elastic intermediary member on a foundation which may be the ground, beams of a structure, etc.

If there is a foundation base rigidly connected to the machine, it can be considered as part thereof. The periodic forces which act on the unit assumed to be rigid are supposed to be known, and the problem is to compute therefrom the movements of the machine and foundation produced by these forces.

Let it next be assumed that the machine under consideration is

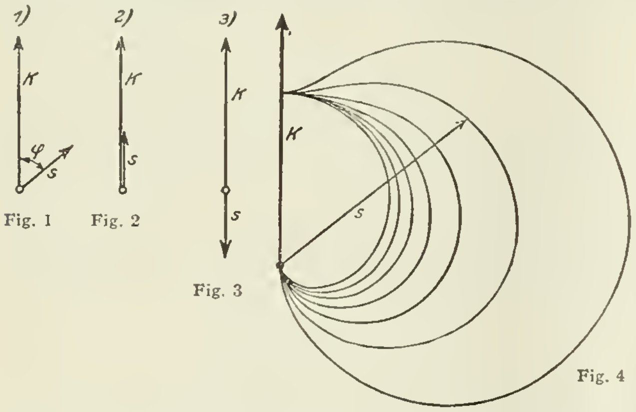

Fig. 1 Fig. 2 Fig. 3 Fig. 4

Figs. 1 to 3 Vectorial Representation of Force K and Displacement s in Foundation Vibrations

Fig. 4 Foundation Function of a Foundation Consisting of an Inert Mass Oscillating with Damping

(The smallest curve corresponds to aperiodic damping; the larger ones belong to smaller values of damping.)

simply floating in space without connection to any kind of a foundation; in that case the inertia forces produced during the motion of the machine by the masses and moments of inertia must be in equilibrium with the forces producing vibrations. Actually, however, the machine does not float in space but rests on a foundation which holds it in a definite position. The first problem, therefore, is to investigate the influence of the "restrictions" produced thereby. Sinusoidal forces or similar moments acting on a foundation produce, when their action is restricted to only small vibrations, sinusoidal motions either of displacement or rotation. The motions generated are, however, as a rule not in phase with the forces producing them but lag somewhat behind them. If, as is usual in alternating-current engineering, the oscillating magnitudes be represented by the projection of vectors on a straight line (Fig. 1) which rotates with an angular velocity corresponding to the periodicity of the oscillations, the behavior of the foundation at any given frequency will be indicated by the vectors of the force K and the motion s, wherein the motion lags behind the force by a phase angle φ. This angle must be between 0 and 180 deg., so long as the energy from the machine is to be transferred to the foundation.

If the foundation were a perfectly elastic spring its motion would be fully in phase with the force producing it (Fig. 2). If, however, the foundation is composed of an inert, freely moving body it will move in a direction opposite to that of the force (Fig. 3). In general, φ may assume any value whatsoever; if it is acute, we approach the case of an elastic spring and the foundation may be called "springy;" if φ is obtuse, the foundation may be described as "massive."

If the frequency changes while the amplitude of the force remains

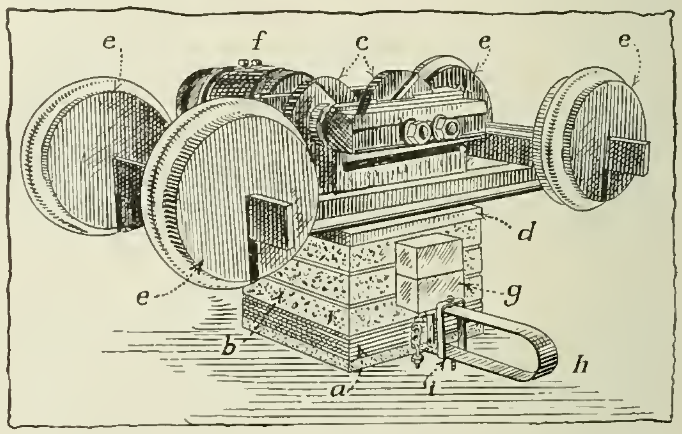

Fig. 5 Device for Investigating the ω Function

constant, the magnitude and direction of the vectors of the motion vary. If the end points of all the vectors of motion produced by the oscillating force at various frequencies be connected, we shall obtain a curve which may be designated as the "foundation function." If the foundation function is known for all the six freedoms of motion, the foundation may be considered as fully determined.

The energy delivered by the vibrations to the foundation may be also determined from the vector diagram as it is proportional to the area of the triangle formed by the vectors K and s.

In simple cases the "foundation function" may be computed theoretically. For example, if the foundation consists of an inert mass held in position by elastic forces and is such that its motions are damped by a friction proportional to the velocity, the foundation functions for the various magnitudes of damping will be somewhat as shown by the family of curves of Fig. 4. At low frequencies the motions and forces will be in phase. With increasing frequency the amplitude and lag of the motion increases, the amplitude reaching its maximum value at the resonance frequency where the motions lag approximately 90 deg. behind the force. From the resonance point on the amplitude begins to decrease while the angle of lag tends to approach 180 deg. At frequencies below resonance the foundation behaves in a springy manner; at frequencies above, like a mass. The foundation function may be also computed for beams yieldingly held at the ends. Since, however, as a rule, the method of holding the beam ends is not known

with sufficient exactness, such computation will not give usefully employable values. In the majority of cases occurring in actual practice, conditions are still more complicated and computation processes cannot therefore be resorted to. Here, however, the foundation function may be determined experimentally, for which purpose apparatus illustrated in the original article (Fig. 5) may be used. On the foundation is laid a plate *a* so perfectly elastic that its change of shape is at each instant proportional to the force acting upon it. For such purpose flat steel plates (Fig. 6) 2.5 mm. (0.1 in.) thick and, say, 30 by 30 cm. (11.8 in. on a side) may be used. These plates should be so held that when loaded they are stressed in bending. It was found by actual test that such plates behaved as if they were practically perfectly elastic. On these springy plates are located three plates *b* made of cork brick, the purpose of which will be indicated below, and on these is placed the vibration generator which produces forces oscillating in a vertical direction. Such a generator consists mainly of two disks *c* with eccentrically distributed masses which rotate about parallel shafts held in a rigid frame. In such an installation the horizontal

of an inclined line an ellipse is produced, the shape of which makes it possible to determine the lag in phase and the magnitude of the beat of the mirror and hence the force acting on the foundation and its motion. The area of the ellipse is a measure of the energy consumed in each vibration.

The stationary mass with respect to which the motion of the foundation is measured is the weight *g* (Fig. 5) held on a base *i* located on the foundation by means of a spring stirrup *h*. The mirror measuring the motion of the foundation is located between the base *i* and the weight *g*. At frequencies from 800 to 2200 per min. the small motions of the mass *g* may be neglected.

By considering the ellipses of vibration at various frequencies one obtains from them point by point the foundation function. Such tests have been carried out on an approximately square concrete plate about 7 m. (23 ft.) long on a side and 27 cm. (10.5 in.) thick, the points under consideration lying in the middle of the slab as well as in the middle of one of the halves. The group of ellipses of vibration obtained in these tests is shown in Fig. 9 where the figures above the ellipses denote the revolutions per minute.

Fig. 6

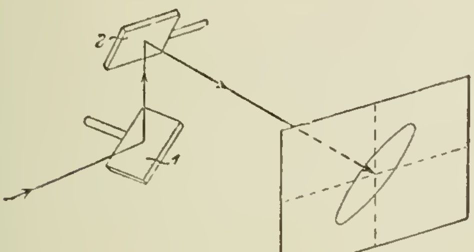

Fig. 7

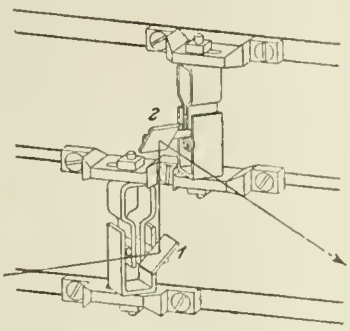

Fig. 8

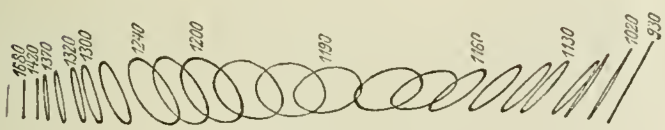

Fig. 9

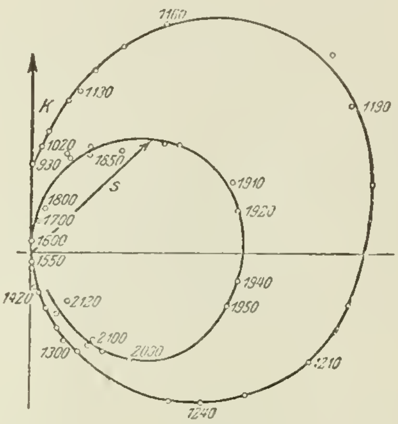

Fig. 10

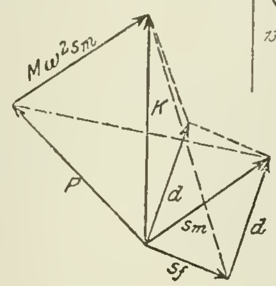

Fig. 11

Fig. 6 Elastic Spring Plate Made of Sheet Steel; Fig. 7 Mirror Arrangement for Investigating Vibrations in Foundations; Fig. 8 Arrangement for Investigating the Behavior of Damping Intermediary Layers; Fig. 9 A Series of Oscillation Ellipses from a Concrete Plate; Fig. 10 ω Function for a Concrete Plate; Fig. 11 Graphical Computation of Vibrations in Foundations

components of the centrifugal forces are eliminated and only pure vertical vibrations remain. The frame of the vibration generator carries the base plate *d* which transmits the vibrations to the cork-brick plates; it is also provided with stiffening girders supporting weights *e*. By changing the size of these weights and the number and thickness of the cork-brick plates *b*, it becomes possible to do away with undesirable vibrations, for example, lateral vibrations of the whole installation. This also provides a means of changing the magnitude of the forces acting on the foundation. The machine is driven by the electric motor *f*. The compression of the spring plate is measured by an optical indicator by means of a mirror, 1, the rotation of which (Figs. 7 and 8) is proportional to the change in shape of the springy plate and hence the forces acting thereon. The ray of light which arrives in a horizontal direction is thrown upward by the mirror 1 on to a second mirror 2, which indicates the motion of the foundation with respect to a sufficiently large stationary mass and also projects the ray of light in a horizontal direction on to a sheet of sensitized paper where it is photographed as a point of light. The axes of the two mirrors cross each other vertically and their masses are so small that they can keep pace with very rapid motions. When oscillations arise in the foundation the first mirror causes the rapidly moving point of light to appear as a horizontal straight line and the second mirror as vertical straight line. If both mirrors oscillate, then the resultant of the motions is an inclined line, provided the mirrors are in phase. If mirror 2 lags in phase as compared with mirror 1, then instead

The foundation function for the middle of one of the halves of the plate at various speeds is given in Fig. 10. As shown there, it consists of two consecutive slices corresponding to the fundamental oscillation and the first upward oscillation of the plate, where the plate has a junction line in the middle. The component of the amplitude normal to the direction of force K represents the measure of the transmitted energy of vibration. The arrangement described is suitable only for the most important vibrations propagating in the vertical direction, but it may be easily applied to the other freedoms of motion.

Effect of an Elastic Intermediary Layer Between the Machine and the Foundation. Such an intermediary layer when acted on by sinusoidal forces undergoes sinusoidal changes of shape. If it is perfectly elastic the compression is in phase with the force, but if a part of the work of deformation is converted into heat the deformation must lag behind the force. As a rule such an intermediary layer has both springy and damping properties.

In order to investigate the behavior of intermediary elastic layers an arrangement was employed similar to that described above for testing the behavior of foundations. In the course of these tests a perfectly elastic steel plate is laid on a sufficiently rigid foundation layer and upon this a plate of the same size made of the material under investigation, for example, rubber, cork, etc., the whole being submitted to the action of a periodic force. The two plates are connected with a double mirror arrangement such as has been described above, mirror 1 measuring the compression

of the perfectly elastic plate and hence the force, and mirror 2 the change of shape in the plate of the material under test (Fig. 8). From the path of the point of light, which, in the case of imperfectly elastic materials, is an ellipse, and with the knowledge of the amplitude of the force, it becomes possible to determine the deformation with respect to magnitude and phase.

Tests with plates 30 by 30 cm. (11.8 in.) and about 4 cm. (1.57 in.) thick have given under static load an angle of lag of phase of 13 to 18 deg. for rubber, of 6 to 7 deg. for cork brick and of 3 to 6 deg. for natural cork. To these values correspond the following figures of the percentage of conversion of the work supplied for the purpose of changing the shape of the body into heat, namely, 23 to 31, 10 to 12, and 5 to 10, respectively. The larger angles of lag are for higher static loads. Furthermore, it was found that the springy action of the materials under investigation,. i.e., of the component of deformation parallel to the direction of force, has been, in the range of frequencies used of 800 to 2000 per min., only from one-half to one-third that which could have been expected, judging by the curves of elasticity obtained at slow changes of load.

Calculation of Oscillations in a Practical Case. A machine of mass M in which there is a sinusoidal vertical force of amplitude P and frequency ω is placed on a foundation having a given experimentally determined foundation function with an intermediary elastic layer of known properties between the machine and the foundation proper. In order to determine the oscillations that arise and the energy of oscillation loss, we take from the graph of the foundation function the amplitude s_f of the foundation (magnitude and direction, Fig. 11) corresponding to force $K = 1$ and frequency ω. The application of force 1 produces in the elastic intermediary layer a deformation d. If we add vectorially d to s_f, the sum s_m gives the motion of the machine which produces force 1 at the foundation. In order to produce this motion in the phase of the inertia resistance of the mass of the machine it is necessary to exercise a force $+ M \dfrac{d^2s_m}{dt^2}$, for which, in the case of purely periodic processes, may be substituted $-M\ \omega^2 s_m$. If we add this amount to K, we obtain in magnitude and direction the force P which must be applied to the machine in order to produce in it the assumed motion. This value, of course, is not the same as that which really acts in the machine. It is only necessary, however, to magnify or reduce the diagram proportionately or change its scale in order that P shall assume the value necessary to produce the desired oscillation process. The energy given off by the machine at each oscillation is represented by the triangle Ps_m, while the triangle Ks_f represents the energy transmitted to the foundation. The difference between these two or the triangle Kd is converted into heat in the elastic intermediary layer. If the machine has more than one freedom of motion the above calculation should be made for every one of them. Because of symmetry, however, the majority of machines have only few freedoms of motion of importance.

For other frequencies the diagram may be plotted in a similar manner, provided only the corresponding values are taken from the foundation function. By plotting the same kind of a diagram it becomes easy to investigate the probable influence of an increase in the mass of the machine or the greater softness of the intermediate layer. The problem may be solved analytically by using complex numbers instead of vectors. (*Zeitschrift des Vereines deutscher Ingenieure*, Nachlieferungsstuck (Appendix), vol. 67, no. 2, Jan. 13, 1923, pp. 33–35, 11 figs., *ctA*)

Short Abstracts of the Month

AERONAUTICS (See Internal-Combustion Engineering)

ENGINEERING MATERIALS

A New Zinc-Base Die-Casting Alloy, Charles Pack. Some die castings are subject to swelling, warping, and deterioration in service. It is claimed, however, that these troubles are attributable to the alloy used in a given casting and not to the die-casting process. In fact, it is claimed that every case of deterioration of die castings known to the author, who is connected with the Doehler Die Casting Company, has been limited to die castings made from zinc-base alloys, and he gives a brief bibliography on the subject of the deterioration of these alloys. The article claims that the Doehler Die Casting Company has developed a non-corrosive permanent zinc-base die-casting alloy which they call Ni-chro-zink. The composition of the alloy is not disclosed further than by its name. Several tests of the material are described and it is claimed that castings will show a tensile strength of approximately 18,000 lb. per sq. in. and an elongation of 4 per cent, and that fine threads, small holes, and slots can be cast without any difficulty. (*The Metal Industry*, vol. 21, no. 2, Feb., 1923, pp. 53–54, 3 figs., *d*)

FUELS AND FIRING

Tempering Coal and Draft Requirements, Thos. A. Marsh, Mem. A.S.M.E. In an investigation made with western coal the author found that proper tempering helps combustion. He describes in some detail his methods of testing and sets forth the following conclusions which he has reached:

1 Added moisture is beneficial with many coals, certainly with most western coals.

2 Properly tempered coal has less resistance to air flow than either very wet or very dry coal.

3 Very wet coal has less resistance to air flow than very dry coal.

4 The theory of steam formation cracking open pieces of coal does not seem to be correct.

5 Properly tempered western coal burns much more rapidly than coal either too wet or too dry.

6 Properly tempered coal burns to a cleaner ash by decreasing the fuel-bed resistance, thereby reducing the burning of holes in the fuel bed.

7 Properly tempered coal causes less siftings than dry coal, therefore fewer holes occur in the fuel bed and less coal has to be rehandled.

Knowing, therefore, that the advantages of adding moisture to many coals far more than outbalance the disadvantages, and having the above brief study of the action of moisture on air flow, some thought can be given how best to add moisture or temper coal.

Only certain general observations can be made on this subject at present, these being based on the experience of many plants with a great variety of coals. Such observations are:

a Moist coal such as obtained when a car of coal has been rained on the previous day, is usually well tempered.

b Extremely wet coal does not burn as well as coal with medium moisture.

c Moisture added an hour or two before burning is more beneficial than moisture added in stoker hoppers.

d The most usual place to temper coal is at the crusher or in the conveyor. The moisture then has time to mix thoroughly with the coal and agglomerate the fine particles.

e With western coals, one of the important features of plant operation is tempering the coal. With a known coal, intelligent firemen soon become expert in judging the best amounts of moisture for proper tempering. This varies with different coals and coal sizes.

f Exhaust steam for tempering purposes gives very satisfactory results and is used quite extensively. (*Power Plant Engineering*, vol. 27, no. 4, Feb. 15, 1923, pp. 215–217, 3 figs., *cp*)

HYDRAULICS

Experiments on Loss of Head in Valves and Pipes of 1/2 in. to 12 in. Diameter, Prof. Chas. Ives Corp, Mem. A.S.M.E., assisted by Roland O. Ruble. Results of 2200 tests on 48 different gate and globe valves and 425 tests to determine pipe friction.

The loss of head due to gate valves 1/2 in. to 12 in. in diameter was measured for various openings, namely, 1/8, 1/4, 3/8, 1/2, 3/4, and fully open. The loss of head due to globe valves 1/2 in. to 2 in. in diameter, was determined under fully open conditions. As a part of the valve experiments the loss of head in pipes 1/2 in. to 12 in. in diameter was determined, and these results are also included in this bulletin. A bibliography of the subject is appended.

The loss of head due to valves and other fittings occurs in part within the valve or fitting and in part as an added loss in the pipe line downstream where normal flow has been disturbed.

Measurement of the loss of head where the downstream piezometer is attached too near the valve will give a loss in excess of that actually produced. From 20 to 25 pipe diameters beyond the valve will probably give the best position for the downstream piezometer opening. It is undesirable to have a greater length of pipe in the gage length than is actually needed to include all valve loss.

The loss of head in new, clean wrought-iron pipe from $^1/_2$ to 12 in. in diameter is given approximately by the formula $H = \frac{0.0319}{d^{1.16}} v^{1.9}$ in which H is the loss of head in feet per 100 ft. of pipe, v the velocity of flow in the pipe in feet per second, and d the pipe diameter in feet.

Globe valves offer from 15 to 40 times the resistance of gate valves for the same size. This ratio increases with the increase in the size of valves.

The length of straight pipe of the valve size which will produce the same loss of head varies from $^3/_4$ to 4 ft. for fully open gate valves and from 20 to 35 ft. for fully open globe valves. In the case of globe valves the smaller valves are equivalent to the greater length of pipe measured in pipe diameters.

The influence of location of downstream piezometer on valve loss is discussed in an appendix. The conclusion reached is that a valve causes disturbed flow in the pipe line downstream for some distance from it and that a piezometer opening which is connected so as to be in this region will be affected, giving a false record of the pressure within the pipe.

Where there is considerable change of section in passing through the valve the pressure head absorbed at that point to produce the higher velocity of flow is partially recovered in the pipe downstream.

Further, if the loss of head due to flow through a valve be obtained from a piezometer within two or three diameters below the valve, the result will be too large. Not until at least fifteen or twenty diameters of straight pipe intervene between the valve and piezometer will the reading show the true loss.

It follows from this that it is desirable to place the downstream piezometer probably 20 to 25 pipe diameters downstream from the valve. (*Bulletin of the University of Wisconsin, Engineering Series*, vol. 9, no. 1, 1922, 132 pp., 55 figs., *eA*)

INTERNAL-COMBUSTION ENGINEERING (See also Railroad Engineering)

New Fuel-Injection Valves for Compressorless Diesel Engines, Herr Roick. One of the great difficulties that have to be overcome in the development of a small high-speed Diesel engine is the variable metering of small amounts of fuel and their atomization within the very short time available in the course of each cycle. This led to intensive work in the development of proper fuel-injection valves and the present article describes the design proposed by Griev and Livens in their British and German patents. (*Motor und Auto*, vol. 17, nos. 23–24, Dec. 20, 1922, pp. 285–286, 2 figs., *d*)

Statax Three-Cylinder Rotary Engine. An interesting power plant on account of its possible use in "auxiliary" sailplanes has just been produced in Germany. This is the "Statax" three-cylinder rotary two-stroke engine which has been designed and built by F. J. M. Hansen. It is stated to weigh but 17.6 lb. complete with propeller and to develop 7.5 hp.

The chief feature of the Statax is that there is no crankcase but merely a cylindrical induction chamber to which the cylinders are bolted, with their closed ends turned inward. The outer ends of the cylinders are open, and the pistons have their skirts pointing outward. It is claimed that the extremely light weight is a result of so designing the engine that all the most highly stressed members work in tension. From the very brief particulars available (from *Flugsport* of Nov. 15, 1922), it is not quite clear how the force of the explosions and centrifugal force is transmitted from the flat steel straps to the connecting rods or their equivalent. It would appear that, instead of connecting rods, the skirts of the pistons are extended outward, the two extensions carrying lugs for the steel straps coming out from the boss which represents the crankpin. These steel straps are bent over the lugs and then twisted so as to be brought edge-on to the air as the engine is turning.

There are no valves, induction and exhaust ports of usual type, closed and opened by the pistons, being used instead. The combustion chamber is at the inner end of the cylinders, and the mixture is transferred to the combustion chamber through bent induction pipes. Centrifugal force is relied upon to get the charge from the induction chamber out of the cylinders.

The cylinders are of steel, machined from forgings, and are provided with fins of the usual type. The pistons are made of aluminum alloy, as is also the induction chamber, which, owing to the tie rods by which the cylinders are held down, does not have any great centrifugal force to resist. Also, instead of the explosion pressure being added to that of centrifugal force on the cylinders, as in ordinary rotaries, it acts in opposition to centrifugal force.

The propeller blades, of which there are three, are bolted to the induction chamber in the spaces between the cylinders. It would, for this reason, appear to be impossible to cowl-in the engine and as the combustion chambers are near the foot of the cylinders, probably this portion will require ample cooling, so that a cowl could not be used in any case.

The magneto fitted is a Bosch of the smallest type, and the plugs are Bosch-Gnome-Lilliput. The magneto is mounted on the back of the engine as is also the oil pump.

The engine is started by injecting a few drops of the fuel through the exhaust ports, when, on swinging the propeller the engine usually starts after one-half turn. Owing to the centrifugal induction system it has been found that the engine will not function with any regularity at speeds below 500 r.p.m. The maximum revolutions (for long periods) is 1600 r.p.m. At that speed it may be assumed that the propeller efficiency will not be very good in a slow machine.

Following are the main dimensions, etc., of the Statax: Bore, 60 mm. (2 in.); stroke, 70 mm. ($2^3/_4$ in.); speed, 1600 r.p.m.; fuel consumption, 0.705 lb. per hp. per hr.; oil consumption, 0.07 lb. per hp. per hr.; total weight, including a propeller of 4 ft. 11 in. diameter, 17.6 lb. These figures, it is stated, are guaranteed. (*Aviation*, vol. 14, no. 9, Feb. 26, 1923, p. 244, *d*)

The Keith-Whatmough Carburetor

New System of Carburation, G. Keith and W. A. Whatmough. Description of a new type of carburetor which was at first developed as a burner for furnaces using gas as a fuel. Fig. 1 illustrates the apparatus in diagrammatic form.

The air blast is connected at A, and is usually controlled by a valve B. The gas supply is connected to the pipe S, and the mixture flows to the burners along the pipe C. The gas supply is controlled by a balanced valve V connected to a sensitive diaphragm D working in a suitable casing. This diaphragm, which is in itself quite light, is placed vertically, so that even its own weight does not influence its action, and it is loaded on one side by the pressure produced in a tube L by the flow of mixture across the end N, which projects into the mixing tube beyond the throat or constriction M. The end N is cut obliquely, and may be partially rotated in the mixing tube, so that the pressure produced in the tube L with a given flow of mixture may be adjusted to suit the limitations of the gas supply pressure. The gas passes by the valve V until the pressure on that side of the diaphragm is in equilibrium with the loading pressure on the other side. Under this condition there is produced a pressure difference across the obturator O which bears a definite relation to the static and velocity effect produced at the moment by the mixture on the end of the tube L.

It would take up too much time to explain fully the complex variations which take place, but it will suffice for the present purpose to state that so long as the loading pressure on the diaphragm is not greater than the gas pressure existing at S, the proportion of gas to air in the mixture will be constant. The particular quality desired is obtained by adjusting the obturator O, so called to distinguish it from other valves in the apparatus. The quantity of mixture is varied by opening or closing the valve B in the air supply.

This was modified to make it suitable for internal-combustion engines still using gas as a fuel. When, however, it was applied to engines burning liquid fuel it began to boil off the liquid, and, what is more, to do it in such a manner as to prevent boiling off the lighter constituents and leaving the heavier. It was decided to carry on this operation piecemeal in a form of flash boiler capable of working with the heat which would be available from the exhaust.

The first successful type of boiler was of a cascade form in which the fuel was introduced at the top and made to trickle downward over a surface of considerable area, while the exhaust was passed in the opposite direction. By means of baffle plates sufficient turbulence was set up in the gases to enable them to give up heat to the plates of the cascade arrangement so that the liquid was completely evaporated before reaching the bottom of the boiler. This arrangement gave a good deal of trouble and was eventually replaced by the one shown in Fig. 2. In this boiler the exhaust from the engine enters at A, and, after impinging on the casing B, which contains the governing mechanism to be described later, passes in the direction of the arrow, downward, to the boiler proper. This consists of a metal plate P carrying a number of staggered square pins C between which the exhaust passes, and thence upward to the exit D. The staggered pins extract a maximum amount of heat from the exhaust while interposing little resistance to its passage. Depending from the plate P, and in thermal continuity with the heated pins is a block E intersected by a number of vertical saw cuts. A cross-gasway F connects the tops of these saw cuts to an upright gasway leading to the governor. The depending portion is surrounded by a box G, the lower part of which is preferably filled with metal chips. The whole boiler is surrounded by an outer casing H, which is lagged with slag wool below the level of the plate P. Fuel is admitted by the pipe J at the bottom of the box G from the fuel tank, which may be either of the gravity or pressure type. Assuming that the boiler has been heated up

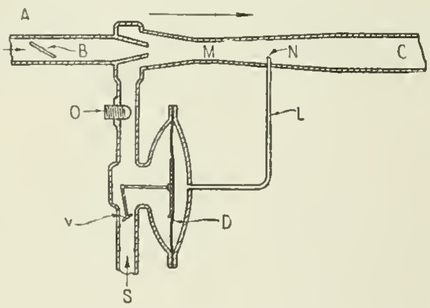

Fig. 1 Gas-Furnace Carburetor-Type Burner

sufficiently and fuel is admitted at the bottom, it will rise through the metal chips until it reaches the lower portion of the block E, which is brought to a point in the center. If the demand for gas is very small, the fuel just touches the lower portions of the saw-cut block and a pressure is set up equal to the head of the fuel entering at J, so that no more will enter. If the demand increases, the level of the liquid rises until it is in contact with a sufficiently large area of surface to give the required quantity of gas. Should the demand be suddenly reduced, the pressure of gas will rise sufficiently to depress the fuel until its area of contact is reduced sufficiently to meet the requirements.

As regards carbon deposits, it was found that none are formed in boilers where completely volatile fuel is boiled without the access of air. In reference to materials it is stated that for light and mixed fuels with equilibrium boiling points not exceeding 200 deg. cent., the boiler proper gives quite satisfactory results if made of cast iron. For fuels with an equilibrium boiling point up to, say, 225 deg. cent., such as Borneo kerosene, brass is a suitable material. With the heaviest practicable fuels, such as lamp oil, with an equilibrium boiling point of, say, 245 deg., an aluminum boiler gives the best results. The reason for the use of different materials is that for the heavier fuels a relatively better thermal conductor is necessary, while with the lighter ones a poorer conductor will suffice.

Means are provided in the boiler to prevent its flooding with the liquid when the latter is not fully vaporized; means also had to be provided to govern the gas. In this case the most satisfactory and practical device was found to consist of a heavy tube with suitable ports. The success of this device is ascribed to the unexpected formation of a kind of soft graphite on the working surfaces, which, with the continuous small movements, due to the pulsation of the engine, produces a beautifully smooth surface which moves with the minimum of friction under the high-temperature conditions prevailing.

Among other things, tests have shown that when an economical mixture was being used on heavy load it was not possible to keep the engine running satisfactorily on a light load or idling, which was found to be due to three causes, the combined effect of which was to reduce considerably the temperature of the exhaust heat, and to the fact that under low-compression pressure a weak mixture failed to ignite, although capable of being fired under high-compression pressure. This led to the development of a device

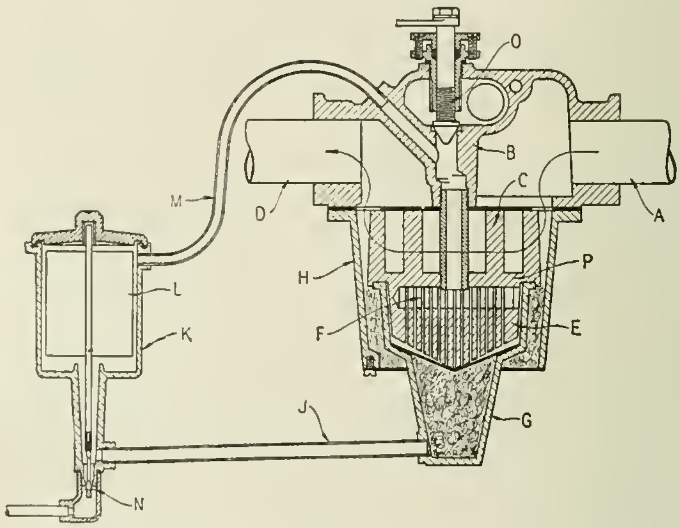

Fig. 2 Fuel Boiler with the Keith and Whatmough Carburetor

for compensation for low-compression pressure when the engine is throttled beyond the mixing point. An auxiliary carburetor is provided to start the engine and heat up the boiler.

The original article reports temperature and road tests. (Paper before the Institution of Automobile Engineers, abstracted through *The Automobile Engineer*, vol. 13, no. 173, Feb., 1923, pp. 55–59, 14 figs., *dA*)

MOTOR-CAR ENGINEERING (See also Railroad Engineering)

A Variable Gear for Motor Cars

Automatic Variable Gear, Eric W. Walford. Description of a mechanism invented by G. Constantinesco, known as the originator of the C.C. gun-control scheme that was used on practically every military aeroplane during the last two years of the war and of wave-power transmission (see Mechanical Engineering, January, 1923, p. 55).

One of the simplest forms of the mechanism is shown diagrammatically in Fig. 3. The shaft of the driving member of prime mover is shown at A, and that of the driven member at B. A crank or eccentric C on the shaft A, by means of a connecting link, causes a lever D pivoted at its lower end to oscillate angularly about its pivot. At its free end this lever has attached to it a pair of links E which at their other ends actuate pawls F, angularly movable around the driven shaft B, and adapted so that one acts on the forward swing of the lever D, while the other acts on the reverse swing, thereby giving a substantially continuous driving action.

So far as it is described there is nothing novel in the mechanism, nor does it act in any way as a variable gear but as a fixed-ratio transmission device only. The central feature of the invention, however, is that the lever D is not pivoted to a fixed, but to a movable member, here indicated by the pendulum G oscillating about

its suspension point at H and carrying the pivot of the lever D at some suitable distance from the point of suspension.

In its broadest and simplest conception the transmission mechanism thus employs between the driving and the driven elements a mechanical device for the storage of energy. This device has a floating connection in the drive, such that if the output of the driving member initially is insufficient to overcome the resistance of the driven member, the energy of the former is stored kinetically in the intermediate receptacle of energy, while the speed of the driving member increases automatically until this stored energy is sufficient to overcome the resistance of the driven member. Conversely, if the resistance of the driven member falls, then a portion of the energy stored between the driving and the driven member is yielded up to the driven member, the amount taken for storage from the prime mover is diminished, and the energy of the latter

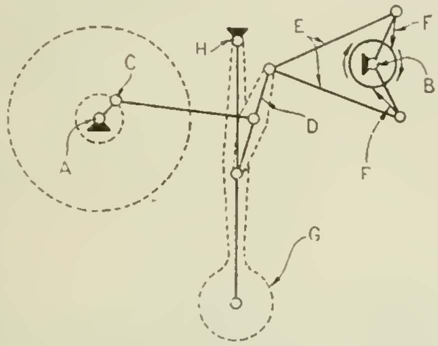

Fig. 3 Diagrammatic View of Constantinesco Automatic Variable Gear for Motor Cars

is then transmitted wholly or in part to the driven member, thus producing in it a corresponding increase of speed.

The action of the mechanism can best be understood by considering that the shaft A is set in motion and that the shaft B is at rest, and (as, for example, would be the case in a motor vehicle) would require a relatively large starting torque to set it in motion. Assuming, therefore, that the driving shaft A is not able to supply by a direct drive (such as would exist if the fulcrum of the lever D were on a fixed member) the torque necessary to start the shaft B in motion, the upper end of the lever D becomes the fulcrum for its angular movements under the operation of the crank C, and the pendulum G commences to swing. Incidentally, it may be noted that the angular motion of the pendulum under these differences is limited to a definite amount, just as would be the motion of the lever D if the pendulum were stationary.

As is well known, the characteristic of a moving body is that the energy stored in it is proportional to the square of its angular or linear velocity. Consequently, the energy supplied by the driving member, which the driven member at first is unable to utilize because it is delivered with insufficient torque, is stored up in the pendulum G. As, therefore, the driving member of prime mover, under these conditions, may be regarded as running light, its speed will increase during the storage of the energy. Here, again, it should be noted that in oscillating movements there is a natural frequency peculiar to the characteristic dimensions of the oscillating member, and that when the rate of oscillation is made otherwise than that which is natural, the frequencies are said to be forced. Such forced frequencies are now produced in the driving of the pendulum, and when its accumulated energy is sufficient, the magnitude of the reaction thrusts on the end of the lever D will cause the latter to move to and fro sufficiently to actuate the pawls F and to start the shaft B in motion.

Such movements of the pawls, at first, will be slight, corresponding to low gear, the ratio of which is accentuated by the speeding up of the prime mover during the storage of energy in the pendulum.

When motion of the shaft B has commenced, and supposing the car to be moving along the level, the resistance will diminish sufficiently for the energy of the driving member so that the supply will now be shared between the driven shaft and the pendulum. The proportion which each receives automatically varies with the resistance to be overcome, the pawls in like manner vary in their angular strokes, and the gear ratio rises or falls automatically in conformity therewith, and with the changes of speed which perforce take place in the prime mover.

The original article gives curves showing the relationship of the driving and driven members under varying conditions of speed and torque. The driving pawls are not of the ordinary tooth type but consist of pads curved around the face of a drum attached to the driven shaft. Their arrangement is such as to insure a secure grip and smooth action, which would not be readily attainable with an ordinary ratchet-and-pawl mechanism.

The most serious objection to the system described as viewed by the author appears to lie in the unbalanced forces set up by the movement of the pendulum, as it is apt to create serious vibrations. (*The Automobile Engineer*, vol. 13, no. 173, Feb., 1923, pp. 52–53, 3 figs., *d*)

POWER-PLANT ENGINEERING

Air-Cooled Condensers. Abstract of patent obtained by the Swedish Ljungström Company. The inventor states that it is sometimes difficult in connection with steam locomotives for the fans used to draw the air through the condenser. He therefore places the fans so close together that they overlap, as shown in the drawing, and the fan blades intermesh more or less after the fashion of the teeth of gear wheels. The fans must, of course, rotate in opposite directions. (British patent no. 189,718, May 1, 1922, published Dec. 7, 1922, abstracted through *The Engineer*, vol. 135, no. 3500, Jan. 26, 1923, p. 107, 1 fig., *d*)

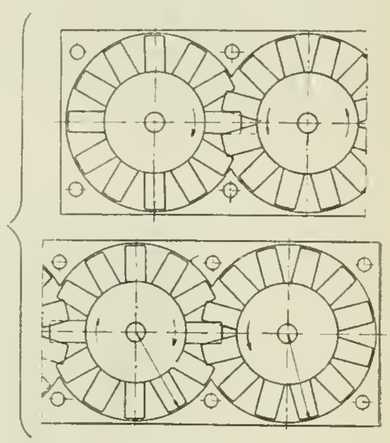

Fig 4 Ljungström Air-Cooled Condenser

A High-Pressure Boiler with Rotating Tubes

Swedish Boiler with Rotating Tubes for 1500 Lb. Pressure, Edvin Lundgren. There are places where an increase of the initial pressure of steam from 300 to 1500 lb. per sq. in. would increase the power obtained from a given weight of steam by from 20 to 60 per cent, and in the case of back-pressure engines or turbines, even 100 per cent or more. With water-tube boilers, however, at least in stationary practice, 350 lb. is considered to be generally the safe limit. In very small boilers steam was produced at higher pressures chiefly by using spiral tubes of a small diameter. There, however, the difficulty of removing sediment proves to be an important obstacle.

There is another factor which, although it has not received much attention, plays an exceedingly important part in the proper service of a boiler, particularly a high-duty boiler. This is the fact that the heat transmitted through the tube walls is far more effectively carried away by water than by steam. In boilers of the ordinary design, equipped with either straight or spiral water tubes, it is, however, practically impossible to keep the inside surface of the heated tubes steadily in contact with the water. On the contrary, the steam generated tends to linger at or near the walls in the form of bubbles, thus increasing the resistance to the flow of heat from the walls. This is, of course, more serious the higher the temperature of the fire and the higher the pressure (and hence the temperature) of the steam produced.

To meet this situation, J. V. Blomquist, a Swedish engineer, designed a new boiler called the "Atmos" in which steam is generated in rapidly revolving tubes. This rotation results in the inside circumference of the tube being entirely covered by a shell of water which is pressed against the walls by centrifugal force. This, in turn, forces the steam bubbles rapidly from the walls into the open central space from which the steam passes out through a central tube of smaller diameter. The diameter of the rotating tubes is made as large as the pressure will permit without requiring an excessive wall thickness.

Moreover, the construction is such that the rotating tubes, or the "rotors," as the inventor calls them, may expand freely without strain. In ordinary boilers it is impossible to avoid those stresses, and it is even impossible to determine them accurately.

The effective cooling of the rotor walls and the freedom from expansion strains make possible rates of evaporation as high as 60 and sometimes even 100 lb. of water per hour per square foot of heating surface. This makes for an exceedingly compact construction.

The rotors form the most important part of the new invention. Referring to Fig. 5, the hot feedwater is admitted through the vertical pipe at the left end to the cover of the stationary bearing housing or shield and enters the rotating part at A in the central pipe shown, which has an outside diameter of $1^1/_2$ in. and revolves in a stuffing box. To keep the packing tight against the pressure of 1500 lb. and simultaneously avoid excessive friction, is of course a serious problem which many practical steam engineers will consider apprehensively. This problem has, however, been solved by admitting oil under pressure to the central distance ring which divides the packing longitudinally into two parts.

The packing material itself consists of ordinary packing braids. The stuffing-box gland is formed like a cap with an opening on the lower side and is tightened by a single bolt located in the center of the bearing shield. This packing has proved to be entirely satisfactory during a continuous service of over twelve months and is distinguished by its low friction. The oil consumption for a 12-rotor double boiler amounts to about one pint in ten hours.

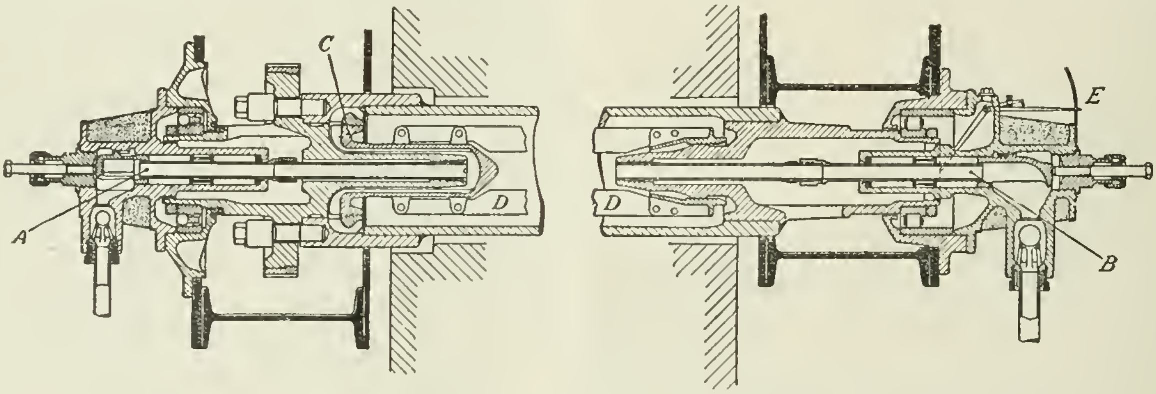

Fig 5 Section through a Rotor of the Atmos Boiler, Showing Feed Connection (Left) and Steam Connection (Right)

The bearing housing on this end of the rotor contains a ball bearing in which the neck of the rotor head revolves. This rotor head is a steel casting and is fastened to the rotor by means of a solid flange on the head, which is kept in place by a number of bolts. To this flange is attached the spur-gear ring which drives the rotor. The head can be readily removed for inspection and cleaning of the interior of the rotor.

The outlet head at the right-hand end of the rotor is screwed into the rotor and then welded to it. The neck of this head, and with it this end of the rotor, is supported by a roller bearing in a manner that allows free expansion and a considerable lateral movement.

As mentioned before, the steam generated is collected in the interior of the rotor and escapes through the central steam-outlet pipe (at the right in Fig. 5) which revolves in a stuffing box of the same construction as that on the water-admission tube.

The chief purpose in designing the flange C like the impeller of a centrifugal pump was to furnish means for measuring the thickness of the water shell and keeping it in correct proportion to the required rate of evaporation.

This is followed in the original article by a discussion of the effect produced by variation in the thickness of the water layer and the various safety devices used.

An installation along the lines described is said to have been made at the Carnegie Sugar Refining Works, Gotenburg, Sweden. Here the steam is generated at a pressure of 900 lb. per sq. in. The boiler is said to have been in continuous daily service under rather unfavorable conditions since December, 1921, and has given satisfactory results. In this boiler the tubes are rotated at 330 r.p.m. (*Power*, vol. 57, no. 7, Feb. 13, 1923, pp. 238–241, 5 figs., *dA*)

POWER TRANSMISSION

Schieferstein Power Transmission by Oscillations. Data on the inventions of the engineer Schieferstein, in connection with the technical utilization of mechanical and electromagnetical oscillations. Schieferstein realizes that all oscillating systems, as for instance pistons operated by cranks, are most favorably employed for yielding useful work if their oscillations are located in proximity to their self-oscillations. In order that such engine parts may follow their self-oscillations, it will be necessary to insulate them mechanically from their driving medium. Hence a system, according to Schieferstein, consists of three essential parts: the energizer, from which the drive originates; the coupling, which transmits the drive upon the freely swinging system; and the energized or resonant part, which yields useful work.

An electrically operated quick-stroke hammer may serve as a practical example of such a system. The energizer in this case would be a crank mounted upon the end of the motor shaft. The stroke of this crank may be very short. As distinct from similar hammers which have already been constructed, the hammer piston is not connected rigidly to the crank by means of a connecting rod, but a coupling spring is interposed between the latter and the hammer piston. If now the turning speed of the electric motor and the self-oscillations of the hammer piston are tuned in respect of each other so that resonance or nearly resonance is produced between the two, the amplitudes of the oscillations of the hammer piston will be far greater than correspond to the stroke of the crank drive. As there is no power required for limiting the stroke of the hammer piston, as would be the case if it were rigidly connected to the crank, and as the reaction upon the crank drive only consists in the pressure of the coupling spring, the energy consumption of the system is said to be much smaller than if the piston were rigidly connected and the crank drive may be constructed with correspondingly smaller dimensions.

The conclusions to be drawn from the example quoted open wide prospects for the possibility of applying this system also to prime movers and power generators in which the forces of acceleration limit the increase in turning speed. The new system may also be employed to great advantage for the driving of mowing-machine knives or gate saws.

Another example shows that Schieferstein's system is applicable also to comparatively slow oscillations. This is the drive of a clock without escapement. Again he uses a crank of small stroke which may be rotated in the customary manner by the weight of the clock. The crank transmits its impulses by means of a connecting rod and through the intermediary of a coupling spring upon an ordinary clock pendulum. The crank as the energizing system and the pendulum as the resonant system must again be tuned relatively to each other in such a manner that resonance is possible. In the present case every revolution of the crank must correspond to one beat of the pendulum. If the pendulum is now set in motion it will receive through the intermediary of the spring just sufficient energy from the crank to keep up its movement, whereas, on the other hand, the coupling spring prevents the crank from causing more than one revolution during one oscillation of the pendulum. It will readily be seen that clocks

working on this system will require only a minimum of weight or spring power and will run for a long time after once being wound up. (*Engineering Progress*, vol. 4, no. 1, Jan., 1923, p. 17, *d*)

PUMPS

Condenser Extraction Pump with Glands under Pressure

Condenser Extraction Pump with Glands under Pressure. Description of a pump recently placed on the market by the Mirrlees Watson Co., Ltd. The chief feature of the new design is the elimination of all air leakage through the gland and stuffing boxes by placing these parts under a pressure corresponding to the external head against which the pump is working. A section of the pump is reproduced in Fig. 6, and serves to show the impeller arrangement and the general details of the design. Two single suction impellers are mounted on opposite sides of the pump suction *A*, and are so arranged that their inlets are facing each other, and the impellers discharge into volutes or pressure chambers *B*. These volutes are interconnected and join up to the common discharge pipe *C*. It will be noted that the two impellers work in parallel,

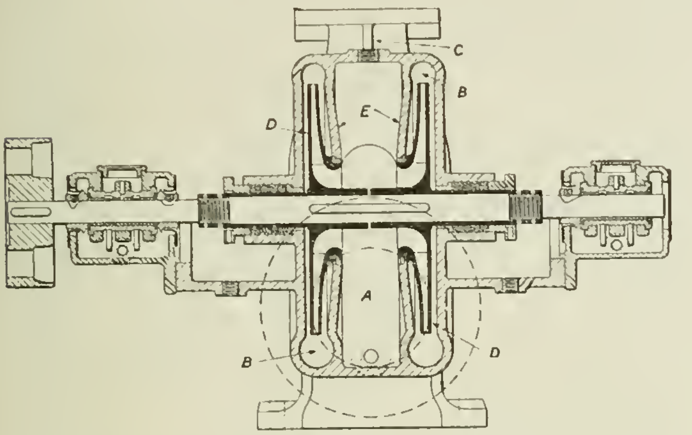

Fig. 6 Mirrlees Extraction Pump with Glands under Pressure

their disposition being such that the end thrust of the one is counterbalanced by the end thrust of the other. The chambers *D* at the opposite ends of the pump casing communicate with the inner ends of the stuffing boxes through which the impeller shaft passes, and are also connected with the volutes by means of the clearance spaces at the peripheries of the impellers. Any possible communication between the chambers *D* and the suction inlet *A* is prevented by the impellers and the diaphragms *E*. The pressure in the chambers *D* therefore corresponds to the discharge head against which the pumps are called upon to work, and as this is well above the pressure of the atmosphere there is no tendency for air to enter the pump casing through the stuffing boxes. As the design is intended for moderate discharge heads, the glands do not require to be very tight in order to prevent leakage.

The casing is split horizontally which facilitates the inspection of the working parts without disturbing the alignment of the pump and motor. The impellers are dynamically and statically balanced and the steel shaft is protected by means of a renewable bronze liner. The new pump has no water seal. The plain stuffing boxes are easily packed, and as the pressure is outwards the hot condensate is not contaminated by the infiltration of oil and grease. The type of pump described is intended for use with a surface condenser, but the design may also be applied to extraction pumps for jet condensers. (*The Engineer*, vol. 135, no. 3502, Feb. 9, 1923, p. 152, 2 figs., *d*)

RAILROAD ENGINEERING

The Next Step in Locomotive Construction, A. F. Stuebing, Mem. A.S.M.E. The author calls attention to the great improvements made in locomotive construction in recent years. He claims that as long as the reciprocating steam engine was the only type of prime mover the locomotive was also well up in the front rank of progress, and it is only since the introduction of the steam turbine and the internal-combustion engine that the efficiency of stationary power plants has shown any marked improvement over the locomotive.

Any new type of motive power if it is to be a success must be adapted to the existing railroad facilities. This means that it must haul a train load approximating that of the steam locomotive and made equal or greater speed. Any new type of motive power should be not only economical in the use of fuel, as simple and sturdy as possible, but, what is perhaps most important, it must be reliable. In a steam locomotive there are very few defects that make it entirely inoperative. It may have leaks and pounds, but it will usually bring the train in somehow.

Fuel economy and locomotive efficiency are not synonymous. The locomotive must be considered as a transportation machine. If a new type of motive power reduces the cost of fuel, but at the same time causes a greater increase in the expenditure for crew's wages, repairs, fixed charges, etc., it is not an economical transportation machine, regardless of its economy from the thermodynamic or mechanical standpoint.

From this the author proceeds to the discussion of the turbine locomotive and the Diesel locomotive, both of which apparently bear important promise for the future but neither of which the author is prepared to fully recommend for the present. (From paper entitled, Are We Due for a Radical Change in Locomotive Construction? read at the January, 1923, meeting of the New York Railroad Club, abstracted through *Railway Age*, vol. 74, no. 5, Feb. 3, 1923, pp. 323–325, *g*)

Report of the Bureau of Locomotive Inspection. Abstract from the eleventh annual report to the Interstate Commerce Commission of the chief inspector of the Bureau of Locomotive Inspection for the year ended June 30, 1922.

The report shows an increase in number of locomotives inspected, with a reduction in the number of defects and number of accidents.

During the year there were 33 boiler explosions, a substantial reduction as compared with the preceding year. Most of these explosions were caused by overheating of the crown sheet due to low water.

Of particular interest is the part of the report dealing with the applications of welding processes. Investigation of accidents where the fusion or autogenous welding process was involved is claimed to support the position previously taken that that process has not yet reached a state of perfection where it can be safely depended upon in boiler construction and repair in places where the strain to which the structure is subjected is not carried by other construction in conformity to the requirements of the law and rules, nor in firebox crown-sheet seams where overheating and failure are liable to occur, nor extensively in repairing long or numerous cracks in side sheets.

Records show that approximately 80 per cent of all autogenously welded seams involved in so-called crown-sheet failures have failed, while only 16.9 per cent of riveted seams have failed under like conditions. The fatalities where sheets tore have been $7^1/_2$ times as great as where they did not tear. From July 1, 1916, to June 30, 1922, autogenously welded seams were involved in 22.1 per cent of the crown-sheet failures, while 44.1 per cent of the total persons killed in crown-sheet accidents were killed where autogenously welded seams were involved.

A large number of accidents have been caused by defective grate-shaking apparatus and the report recommends that a power grate shaker be applied to all coal-burning locomotives. Among the other recommendations the following may be cited:

That power-reversing gears be applied to all locomotives and that air-operated power-reversing gears have steam connections with the operating valves conveniently located, so arranged that in case of air failure steam may be quickly used to operate the reversing gears.

That all locomotives, where there is a difference between the readings of the gage cocks and water glass of two or more inches under any condition of service, be equipped with a suitable water column, to which shall be attached three gage cocks and one water glass, with not less than 6 in., preferably 8 in., clear reading, and one water glass with not less than 6 in., preferably 8 in., clear reading on the left side or back head of the boiler. (*Railway Age*, vol. 74, no. 8, Feb. 24, 1923, pp. 473–474, 4 figs., *gA*)

Is the Steam Locomotive Out of Date? L. G. Coleman. This question is raised by the author who is assistant general manager of the Boston and Maine Railroad. His thesis is essentially as follows:

The steam locomotive today is probably the most uneconomical and unsatisfactory machine in industry. In recent years enormous improvements have been made which have very much increased its efficiency as far as power production is concerned, but these same improvements have so increased the cost and difficulty of maintenance that the time lost in terminals practically wipes out savings due to fuel economy obtained by modern devices and increased unit power.

The inherent weakness of the steam locomotive is its boiler, since when the boiler is out of commission the whole locomotive is out of commission. The limiting factor of long engine divisions is usually the boiler and not the machinery, and a machine that is otherwise ready for service always loses time in terminals by boiler-maintenance conditions, a loss which can be conservatively put down at 50 days each year.

So long as we continue to carry a portable steam boiler on each of our power plants there will be delays, such as washouts, hydrostatic tests, repairs due to leakage and numerous others.

The author believes that this situation can be made better by the use of Diesel engines than by electrification and gives the following calculation as to the former. A modern Santa Fe type locomotive with fully loaded tender weighs approximately 283 tons and will develop, say, 1800 kw. To produce the same useful output by Diesel-electric drive requires a brake horsepower of about 2600, which at 60 lb. per hp. means one or more Diesel engines of an aggregate weight of 78 tons, one or more generators not over 12 tons, a chassis to carry this load, say, 40 tons, or a total weight of 130 tons, to which, say, 20 tons should be added for radiation and accessories.

The possibilities in design are so varied as to offer many opportunities for economies, such as the use of three or four Diesel-engine generator sets mounted on a single chassis which would permit a certain freedom of electrical combinations as to voltage and amperage.

In the discussion which followed the present-day locomotive was vigorously defended, and, in particular, the great value of improvements was pointed out. Thus, it was stated that superheaters are reported to have saved their first cost in from two to three months, feedwater heaters in from 18 months to two years, brick arches in a month, and that boosters save their cost in increased tonnage revenue in from 15 days to three months.

Among other things advocated by the author is the formation by the railroads of the country of a joint bureau for research. (*New England Railroad Club*, Jan. 9, 1923, original paper pp. 190–199 and discussion pp. 199–239, illustrations in the discussion, *g*)

Diesel-Electric Railroad Car, Prof. P. Ostertag. Description of a railroad car intended to operate light trains and built by the Sulzer Brothers at Winterthur.

The car is equipped with two trucks, one of two and the other of three axles. The three-axle truck carries the Diesel engine and the electric generator, which latter is connected to the motor by a flexible coupling. The two-axle truck carries two electric motors acting on the driving shafts. They are located in a cast-iron casing and operate, through gear wheels, layshafts connected by cranks to the driving shafts.

The machinery of the present installation is much simpler than that used before. The crankshaft of the six-cylinder motor is in the longitudinal axis of the car, while the camshaft is parallel to it and runs at half the engine speed. The cylinders are in V, the exhaust pipe being located between the cylinders and the fuel tank on top of it. The Diesel engine is designed to produce 200 hp. at 440 r.p.m., but may carry a load up to 250 hp. for a short period. This gives the car a speed of 70 km. (43.5 miles) per hr. and 60 km. (37.28 miles) with a 30-ton trailer.

The operation of the engine has been simplified and air is no longer used for fuel injection, the atomization of the fuel being effected by means of a part of the explosion gases themselves. As the fuel vaporizes rapidly it ignites spontaneously without the help of either a magneto or hot tube. The compressor of the ordinary Diesel engine is therefore eliminated.

Even starting is effected without compressed air, the generator being fed from a set of storage batteries and acting then as a motor. The cooling water of the cylinders operates in a closed cycle, the hot water being carried by a centrifugal pump into a tubular radiator located on the roof of the car. Means are also provided for varying the surface available for cooling in accordance with the air temperature; in winter the hot water is used for heating the car. A thermometer placed in view of the engineer permits him to control the temperature of water at all times.

As regards the electrical part of the equipment, it is stated that the current is generated by an eight-pole machine with separate excitation and having a continuous output of 140 kw. at 300 volts.

The current to the traction motors is supplied through a Ward-Leonard distribution. The Diesel engines operate at constant speed and full load irrespective of the speed of the car, which insures the minimum consumption of fuel. The traction motors are of the series type with six main poles and six interpoles.

Numerous devices described in the original article are provided for insuring safety of operation. For example, the engineer cannot release the controller, as the circuit opens the instant he does so. These devices in the main do not differ, however, from similar apparatus used on high-speed electric traction lines in America. Numerous tests in Switzerland have shown the simplicity of operation and reliability of the new equipment. Among other things it was found that on down-grade stretches Diesel engines could be shut off, giving an additional economy in the consumption of fuel. The fuel costs generally were found to be very low as compared with similar steam equipment. It is claimed that the cost of operation of the Diesel-driven railroad car is much lower than that of a gasoline-driven car and that in addition a heavy-oil equipment is safer from the fire hazard point of view. (*Bulletin Technique de la Suisse Romande*, vol. 49, no. 2, Jan. 20, 1923, pp. 21–26, 9 figs., *d*)

SPECIAL MACHINERY (See Power Transmission)

TESTING AND MEASUREMENT

Van West Portable Set for Testing Gearing. Description of an apparatus developed in Holland which can be used with the gears in place, provided it is found convenient to measure the axial pitch of the helical teeth rather than the circumferential.

The apparatus consists of a round bar, denoted by *A* in Figs. 7 and 8, and a square steel bar. The square bar is fixed in a groove cut parallel to the axis, and serves as a bed over which the measuring devices can be moved. With the pinion and wheel in true alignment, this square bar will always be parallel with the axes of the wheels when the bar *A* is placed as indicated in Fig. 8. The bar *A* is magnetized, and thus fits itself in between the wheels, and is held firmly without risk of distortion. A rod *C*, which can be clamped by a set screw, as best seen in Fig. 7, serves to adjust the angular position of the magnetized bar by abutting against the pinion shaft as indicated in Fig. 8. On the square bar a block, *B*, is arranged to slide. This block carried the two fingers, *E* and *D*, clearly shown in Fig. 7. The finger *E* can be clamped at any desired point of the rod *F* by the milled head shown, while the finger *D* has a tail piece which abuts against a dial micrometer as indicated. Both fingers can be rotated around or with their supporting rod, *F*, which is secured by a clamp, as shown in Fig. 7. An adjustment is provided at *H* for bringing to zero the indicator of the dial micrometer *G*. If the whole apparatus is pressed in an axial direction, the ends of both fingers come into contact with the flanks of consecutive teeth and the reading of the dial micrometer is recorded. A second set of readings is taken after shifting the apparatus one pitch forward, the operation being repeated till a complete record is obtained. Mr. Van West states that in the case of a pair of smoothly running marine gears, on which he made measurements as above described, the greatest difference found in the axial pitch was only 0.03 mm., or about 0.0012 in.

The device can also be used for testing the teeth of pinions before being put in place. To this end the pinion is laid on a flat surface, as indicated in Fig. 10, and the bar *A* held between the pinion and an angle plate, the measurements being made as before. For testing the alignment of gears the apparatus is placed as indicated in Fig.

9, and the bar turned round until one end of the edge of the square bar touches the teeth. A feeler gage, inserted under the other end, measures the error of alignment. (*Engineering*, vol. 115, no. 2977, Jan. 19, 1923, pp. 74, *d*)

Radiography of Metals at Watertown Arsenal, H. H. Lester. Of interest because of the pioneering nature of the work and unusual completeness of the apparatus available.

The radiographic process is essentially a photographic process. The metal to be radiographed is exposed between the target of a Coolidge X-ray bulb and the photographic film. After exposure the negative is developed in the ordinary way. The photograph obtained is unlike an ordinary photograph in that the latter is superior to the radiograph in the greater amount of surface detail. The radiograph, however, in addition to some surface detail shows in one picture details of both surfaces which can be secured with the camera only by taking two pictures from two sides; further, the radiograph shows details of internal structure which the ordinary photograph does not show at all. In a radiograph white spots represent thin metal. This may be due to the presence of cavities or geometry of the casting. Unfortunately, the majority of the illustrations in the original article cannot be reproduced, thus making it impossible to abstract certain parts of considerable interest.

In radiography it is important to know through what thickness of metal pictures may be taken. Thirty minutes is the upper limit of practical exposure time in the process used at the Watertown Arsenal, although in cases of special importance longer time could be given without, however, corresponding return in penetrability.

Properly developed radiographs indicate not only the presence of defects such as gas cavities but even their exact dimensions. Of still greater importance perhaps than the exact dimensions of the flaws is the question of their detectability. Experiments carried out at the Laboratory of the Watertown Arsenal indicate that where the linear dimension of the flaw, i.e., the dimension parallel to the axis of the X-ray beam, is approximately equal to $1^1/_2$ per cent of the total thickness of the metal in the region adjacent to the flaw, the image may be distinguished. For practical working conditions detectability is placed at 2 per cent, which means that a cavity 0.05 in. in diameter can be detected in metal 2.5 in. thick.

To locate a cavity within the metal the stereoscope is used. In making a stereoscopic examination the area to be radiographed is arranged so that the center of the area, the center of the film, and the target are in line; then the bulb is moved 3 cm. (1.18 in.) to one side of the center line and the exposure made. A second negative is made with the bulb 3 cm. (1.18 in.) to the other side of the center line. These two negatives after development are placed in a stereoscope so arranged that the films may be as far from the eye as they were from the target of the bulb when the exposure was made. When the machine is properly adjusted the picture stands out in bold relief. The surface markings and structural details serve to outline the picture, and the faults appear in their proper places within the material. The picture is quite striking and gives the illusion of looking at a transparent model of the casting. By reversing the negative this model may be turned completely over and one may look through the casting from the other side. The method permits locating details with reference to other details of internal structure. (*Army Ordnance*, vol. 3, no. 16, pp. 210–215, 10 figs., *deA*)

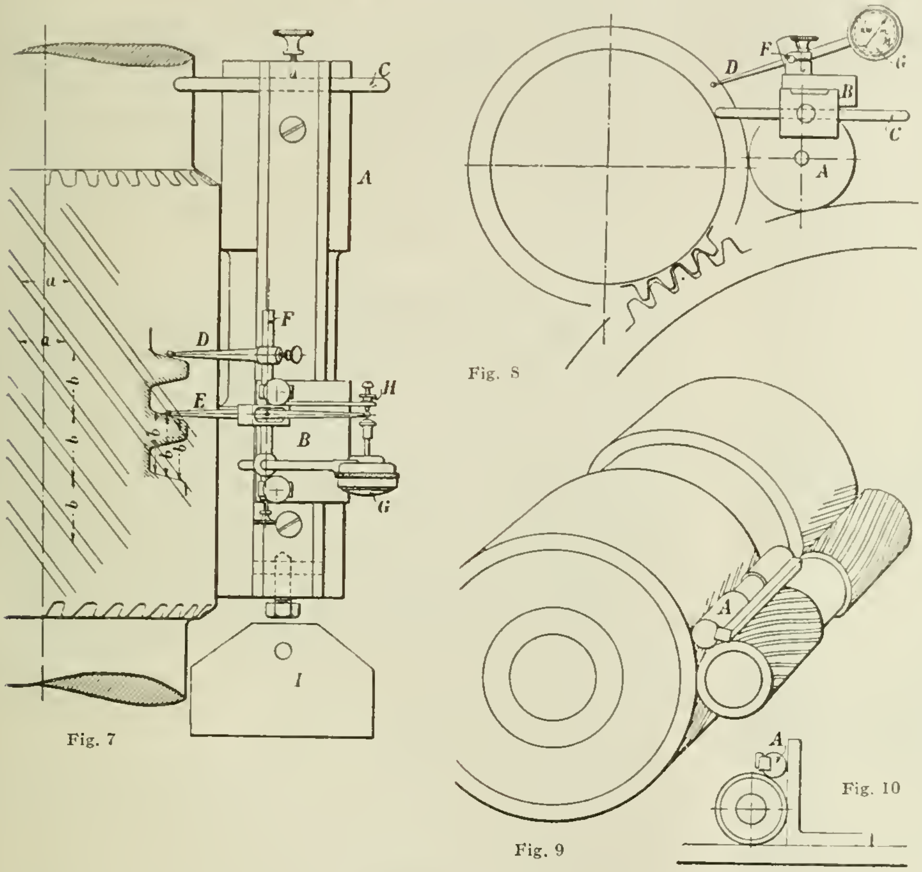

Fig. 7 Fig. 8 Fig. 9 Fig. 10

Figs. 7 to 10 The Van West Gear-Tooth Testing Appliance

THERMODYNAMICS

Variation of the Specific Heat of Air with Temperature. An article based on a paper read in January before the Faraday Society in London by W. G. Shilling of the East London College, based on experiments carried out by himself and Prof. J. R. Partington.

In the present experiments, the method followed was that of determining the ratio C_p/C_v from the velocity of sound in the gas at definite temperatures. The article describes the method used and gives the results obtained, reproduced in Table 1, where T is the temperature in deg. cent. absolute and V the velocity of sound in meters per sec.

The investigators do not rely upon their values at temperatures above 800 deg. cent., because with the heating tube used it proved difficult to secure a sufficiently long central tube portion of uniform temperature, and experiments are being continued with longer tubes.

For the range up to 700 deg., however, the equation $C_v = 4849 + 0.00036\ T$ (in gram calories) would hold, and that formula, which is in good agreement with previous work, together with the concordance of the observations, places the knowledge of the specific heat of air on a much firmer basis than before.

TABLE 1 VARIATION OF SPECIFIC HEAT OF AIR WITH TEMPERATURE FROM EXPERIMENTS BY J. R. PARTINGTON AND W. G. SHILLING

T	V	C_p/C_v	C_v	C_p
288	340.65	1.403	4.952	6.945
373	387.16	1.399	4.985	6.974
473	435.44	1.396	5.017	7.004
573	478.80	1.393	5.053	7.039
673	518.30	1.389	5.098	7.084
773	555.10	1.387	5.130	7.115
873	589.35	1.385	5.157	7.142
973	621.53	1.382	5.197	7.182
1,073	651.87	1.379	5.237	7.222

Professor Partington considers the figures reliable within 0.5 per cent up to 400 deg. cent. and within 1 per cent or 2 per cent for the higher temperatures. Beyond this, however, the reliability of the equation of state comes in, and possibly preference might be given to the Dieterici equation as compared with that of Berthelot, the former covering a wider range of temperatures. (*Engineering*, vol. 115, no. 2977, Jan. 19, 1923, pp. 82–83, 2 figs., *eA*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general, *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

ENGINEERING RESEARCH

A Department Conducted by the Research Committee of the A.S.M.E.

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Mechanical engineers and investigators who desire assistance in locating special instruments, apparatus, or supplies for use in their laboratories are invited to avail themselves of the resources of this organization.

The address for inquiries is Information Service, National Research Council, Washington, D. C.

Résumé of the Month

A—Research Results

The purpose of this section of Engineering Research is to give the origin of research information which has been completed, to give a résumé of research results with formulas or curves where such may be readily given, and to report results of non-extensive researches which in the opinion of the investigators do not warrant a paper.

Aeronautics A1-23. PREPARATION OF LIGHT ALUMINUM-COPPER CASTING ALLOYS. See *Non-Ferrous Metals A2-23.*

Corrosion A1-23. PROTECTIVE METALLIC COATINGS FOR THE RUSTPROOFING OF IRON AND STEEL. This subject is thoroughly covered by Circular No. 80 of the Bureau of Standards, the second edition of which has just been issued. The nature of metallic corrosion and the principles underlying methods of prevention are discussed in the Introduction. Then follow chapters on types of coatings and methods of application, microstructure with numerous micrographs, preparation of surface before coating and accompanying effects upon the mechanical properties of the steel, methods of testing coatings, and finally recommendations concerning different methods. A selected bibliography on corrosion and its preventive metallic coatings is given as an appendix.

Apply to the Superintendent of Documents, Government Printing Office, Washington, D. C. Price 20 cents.

Electricity Utilization A1-23. ELECTRIC BRASS-FURNACE PRACTICE. See *Non-Ferrous Metals A1-23.*

Forest Products A1-23. MOISTURE-RESISTANT COATINGS FOR WOOD. Technical Note No. 181 recently issued by the Forest Products Laboratory, Madison, Wis., describes an interesting investigation of the relative merits of the various methods now employed for coating wood to protect it from moisture. In a table at the end of this report 17 methods of coating wood are rated according to their efficiency.

Foundry Equipment, Materials and Methods A1-23. ELECTRIC BRASS-FURNACE PRACTICE. See *Non-Ferrous Metals A1-23.*

Framed Structures. A1-23. COMPRESSION TESTS OF STRUCTURAL-STEEL ANGLES. This article presents the results of compression tests of 170 structural angles, made at the Pittsburgh branch of the Bureau of Standards. The object of the tests was to determine the ultimate compressive strength of angles fastened at the ends in such ways as would closely correspond to their connections in the construction of transmission towers. There was also tested a series of angles with square ends. An end fixation factor was found to represent satisfactorily the effect of different types of end connections.

This paper was prepared by A. H. Stang and L. R. Strickenberg. It is known as Technologic Paper No. 218 and may be obtained for 10 cents from the Superintendent of Documents, Government Printing Office, Washington, D. C.

Fuels A2-23. COAL ANALYSES FROM TWENTY-FIVE LABORATORIES COMPARED. The Bureau of Mines has recently conducted a study of results obtained in analyzing similar samples of coal and coke by twenty-five laboratories throughout the country, in comparison with results obtained in the Bureau's coal laboratory at Pittsburgh. The comparison is based on the average of 24 analyses by the Bureau of Mines on each kind of coal, and curves are shown giving the deviation from this average analysis, together with deviations from the check limits of the American Society for Testing Materials.

This report of Investigation, Serial No. 2432, was prepared by A. C. Fieldner, H. M. Cooper, and F. D. Osgood.

Iron and Steel A1-23. PROTECTIVE METALLIC COATINGS FOR THE RUSTPROOFING OF IRON AND STEEL. See *Corrosion A1-23.*

Iron and Steel A2-23. EFFECTS OF CARBON AND MANGANESE ON THE MECHANICAL PROPERTIES OF PURE IRON. This paper which was prepared by R. P. Neville and J. R. Cain of the Bureau of Standards describes the preparation and mechanical properties of an extensive series of pure alloys of electrolytic iron, carbon, and manganese whose compositions were so chosen as to bring out the specific effects on pure iron of additions of manganese, carbon, and carbon and manganese together in varying proportions. The maximum content each of carbon and manganese in each series is about 1.6 per cent; the minimum, 0 per cent, or pure iron.

Address Superintendent of Documents, Government Office, Washington, D. C. Price 10 cents.

Iron and Steel A3-23. STRUCTURE OF MARTENSITIC CARBON STEELS AND CHANGES IN MICROSTRUCTURE WHICH OCCUR UPON TEMPERING. H. S. Rawdon and S. Epstein have recently published as Bureau of Standards Scientific Paper No. 452 the results of their investigation in this field. This study of the changes in structure resulting upon tempering was made in a series of 6 carbon steels ranging from 0.07 to 1.12 per cent carbon, quenched from temperatures varying from 750 to 1250 deg. cent. and tempered for different lengths of time at 100 to 650 deg. cent. Upon quenching, martensite is formed throughout each austenite crystal in a manner strictly analogous to the freezing of solid-solution alloys. A redistribution of carbon takes place and the conspicuous martensite plates are found to be distinctly lower in carbon than the "filling material" between the plates. The enrichment of the carbon in the "filling material" may be great enough in some steels to allow small patches of austenite to persist after quenching.

This report includes reproductions of a large number of micrographs. Address the Superintendent of Documents, Government Printing Office, Washington, D. C.

Metallurgy and Metallography A1-23. STRUCTURE OF MARTENSITIC CARBON STEELS AND CHANGES IN MICROSTRUCTURE WHICH OCCUR UPON TEMPERING. See *Iron and Steel A3-23.*

Non-Ferrous Metals A1-23. ELECTRIC BRASS-FURNACE PRACTICE. In 1911 no electric furnace suitable for melting brass was in existence. The Bureau of Mines then began to study the problem experimentally and to encourage brass melters, electric-furnace designers, and electric generating stations to study it also.

The present report, Bulletin No. 202 prepared by H. W Gillett and E. L. Mack, is published to record the progress so far made in melting brass electrically; to aid the plants which have not yet taken up such melting by pointing out the types of furnaces available, describing their performance and indicating their possibilities and their limitations; and to encourage further experimentations with and the development and installation of electric brass furnaces. It also summarizes the theoretical advantages of electric brass melting.

Eighty different types or different makes of the same type of electric furnace were used in the investigation and are described in this Bulletin of 350 pages.

Address the Superintendent of Documents, Government Printing Office, Washington, D. C. Price per copy 50 cents.

B—Research in Progress

The purpose of this section of Engineering Research is to bring together those who are working on the same problem for coöperation or conference, to prevent unnecessary duplication of work, and to inform the profession of the investigators who are engaged upon research problems. The addresses of these investigators are given for the purpose of correspondence.

Air B1-23. FLOW OF AIR THROUGH ORIFICES. See *Fluid Flow B1-23.*

Fluid Flow B1-23. FLOW OF AIR THROUGH ORIFICES. Under the direction of Associate Professor J. A. Polson of the department of steam engineering of the University of Illinois an investigation on the above subject is now under way. Special apparatus has been designed and built for the tests by F. W. Martin and F. C. Linn.

The air is being weighed in the air weighing plant and passed through the orifice. Various methods of determining the flow at the orifice are to be employed and the results compared with the weight determined from the weighing plant. The calculation of values for the coefficients of flow of the several types of orifices and short tubes employed will then be a simple matter.

Friction and Allied Subjects B1-23. Friction Pressure Drop in Ammonia Pipe and Fittings. See *Refrigeration B1-23.*

Refrigeration B1-23. Friction Pressure Drop in Ammonia Pipe and Fittings. As part of program of research in refrigeration the Engineering Experiment Station of the University of Illinois is undertaking an investigation on this subject. These experiments are being directed by Prof. H. J. Macintire and Mr. J. P. Mullen.

F—Bibliographies

The purpose of this section of Engineering Research is to inform the profession of bibliographies which have been prepared. In general this work is done at the expense of the Society. Extensive bibliographies require the approval of the Research Committee. All bibliographies are loaned for a period of one month only. Additional copies are available, however, for periods of two weeks to members of the A.S.M.E. These bibliographies are on file at the headquarters of the Society.

Ceramics and Glass F1-23. This bibliography covers the technical journal articles and Government reports which the Bureau of Mines have consulted during their investigations on this subject. It covers six typewritten pages and is known as Bureau of Mines Reports of Investigations, Serial No. 2437.

CORRESPONDENCE

Contributions to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities and policies of the Society in Research and Standardization.

Mathematical Determination of the Modulus of Elasticity

To the Editor:

I read with interest the communication from Mr. David Guelbaum on the above subject in the December issue of Mechanical Engineering, also Mr. Wm. R. Bryans' comments thereon in the February issue. Perhaps the following suggestions would be of interest.

1 Regarding limitations of theory, for a thin strip of material such as must be used in these experiments the error due to assuming an infinite radius of curvature is by far the least of the errors involved. The common theory is only 7 per cent in error when applied to hooks, where the sections are deep and the radii of the order of two or three inches. (See Elasticity and Resistance of the Materials of Engineering, by Wm. H. Burr.)

2 It must be noted that much depends on the accuracy of determination of the moment of inertia I. Suppose we use a strip of metal 0.0500 in. thick by 0.200 in. wide. Let us vary both dimensions by 0.0010 in.

$$I = \frac{b\,h^3}{12} \quad \therefore \; dI = \frac{\partial I}{\partial b}\,db + \frac{\partial I}{\partial h}\,dh = \frac{h^3}{12}\,db + \frac{h^2 b}{4}dh$$

$$\frac{dI}{I} = \frac{db}{b} + \frac{3}{h}\,dh = \frac{0.001}{0.200} + \frac{3}{0.05} \times 0.001 = 0.065 \text{ or } \pm 6.5 \text{ per cent.}$$

Using ordinary machine methods, we may then be as much as $6^1/_2$ per cent in error, even though our other sources of error are negligible. For accurate work our test piece must be ground to size, within ± 0.0001 in.

3 If the type of testing machine should prove to have merits for special work, as it probably will, the form of machine described is handicapped by a complicated mathematical formula. This handicap may be removed by redesigning the machine.

We will agree that $M = EI/\rho$. If we can make ρ = constant, our mathematical work becomes absurdly simple. To do this, it is only necessary to apply a *couple* at the end of the strip. The moment at all points will be constant, E and I are assumed constant, so the neutral axis becomes a circular arc.

The mechanism would be as follows: One end of the strip would be rigidly clamped in a fixed vise and the other end clamped to a vise on a movable carriage on wheels. A capstan drum on the movable carriage would have a cord about it, the ends passing over pulleys fixed to the bedplate, and supporting weight pans. A slight initial deflection would be produced by adding weights to one pan. The position of the end of the strip could be read with a microscope. More weights would be added to the pan, and the new position of the strip end determined. We may be sure of having eliminated initial position errors if $M\rho$ = constant = EI (for elastic materials, of course).

Garden City, L. I., N. Y. Edward Adams Richardson.

To the Editor:

Referring to the letter in the December issue of Mechanical Engineering from David Guelbaum on the mathematical determination of the modulus of elasticity and the comment thereon by Wm. R. Bryans in the February issue, I would call attention to some of the difficulties encountered in calculating the modulus of elasticity from experiments with thin strips.

1 In bending a rod of rectangular cross-section, for example, Fig. 1 (a), the cross-section is assumed to remain plane. Now, let us denote by $d\theta$ the small angle between two neighboring cross-sections, by ρ the radius of curvature, and by δ the extension of any fiber at a distance z from the neutral axis. Then the unit elongation of the fiber under consideration is—

$$e = \frac{\delta}{\rho d\theta} = \frac{z}{\rho} \quad \ldots\ldots\ldots\ldots [1]$$

The corresponding stress is—

$$p = eE = \frac{zE}{\rho} \quad \ldots\ldots\ldots\ldots [2]$$

and integrating over the entire cross-section we obtain the well-known equation of the elastic line—

$$M = \frac{EI}{\rho} \quad \ldots\ldots\ldots\ldots [3]$$

Contrary to Mr. Bryans' statement, there is nothing in this equation that requires the radius of curvature to be practically infinite. The underlying assumptions are (1) that the cross-sections remain plane and (2) that Hooke's law applies. Let us see what this means. In order to be within Hooke's law the maximum stress must not exceed the elastic limit of the material. This stress we obtain from [2] for $z = +h/2$, whence—

$$p_{\max} = \frac{hE}{2\rho} \text{ or } \frac{\rho}{h} = \frac{E}{2p_{\max}}$$

Now for iron $E = 3 \times 10^7$ lb. per sq. in. and $p_{\max} = 3 \times 10^4$ lb. per sq. in., so that—

$$\frac{\rho}{h} = \frac{3 \times 10^7}{2 \times 3 \times 10^4} = 500$$

Therefore the sole proviso in our experiments is that for material such as iron the radius of curvature must be large as compared with the height of the cross-section. The curvature itself may not be large, but in that case the height of the cross-section must be exceedingly small. It follows that because of convenience we shall be obliged to experiment with thin strips of metal where the distortion of the cross-sections must be taken in consideration.

As is well known, an elongation e in one direction causes a contraction in perpendicular directions equal to e/m, where m is Poisson's ratio. Thus [see Fig. 1 (b)] on the convex side with respect to the elastic line the cross-section will be subject to lateral

contraction and on the concave side, where the longitudinal fibers are under compression, there will be lateral dilatation in the plane of the cross-section. As a consequence the cross-section distorts as shown in Fig. 1 (*b*); the neutral axis cannot therefore remain straight and it is easy to see that its curvature will be $1/m\rho$. Until the width b of the cross-section is of the same order as the height h and h/ρ is a small quantity, the additional deflection due to this curvature will be a small quantity of second order, which can be neglected. In this way the fact of the bending of the neutral axis will not interfere with the assumption that the cross-sections remain plane.

2 Now consider a thin, wide strip bent as shown in Fig. 2 (*a*). The full lines of Fig. 2 (*b*) are the boundaries of a cross-section before bending, and if we apply the foregoing considerations we shall arrive at the conclusion that the cross-section distorts as shown by the dotted lines.

Experiments, however, show that this is not the case. It will be found that the middle part of the cross-section remains as before and distortion occurs practically only near the edges as shown in Fig. 2 (*d*). The reason for this behavior is plain. We must not forget our fundamental assumption, which is that bending consists of a rotation of the bar elements around the neutral axis and that the elements of a plane cross-section before bending remain in a plane after bending. This hypothesis has been proved to be substantially true for straight bars of constant cross-section. This being the case, it is evident that the neutral axis must remain substantially such a straight line as, for instance, *x-x*, Fig. 2 (*b*). Now it will be seen that if the distortion of the cross-section is as assumed in Fig. 2 (*b*), the parts *d*, *d*, will lie entirely in the tension zone. If we then cut a longitudinal strip from the bar near its edges, as represented in Fig. 2 (*c*), the cross-sections 1-1 and 2-2 will be subject to tensions only, whose resultants are the forces P. Their resultant is the force R, which evidently prevents the cross-section through the strip from curving upward as assumed in Fig. 2 (*b*). This at once explains why the distortion of the cross-section is more like that shown in Fig. 2 (*d*) and also confirms the statement that the fundamental hypothesis of bending is substantially true.

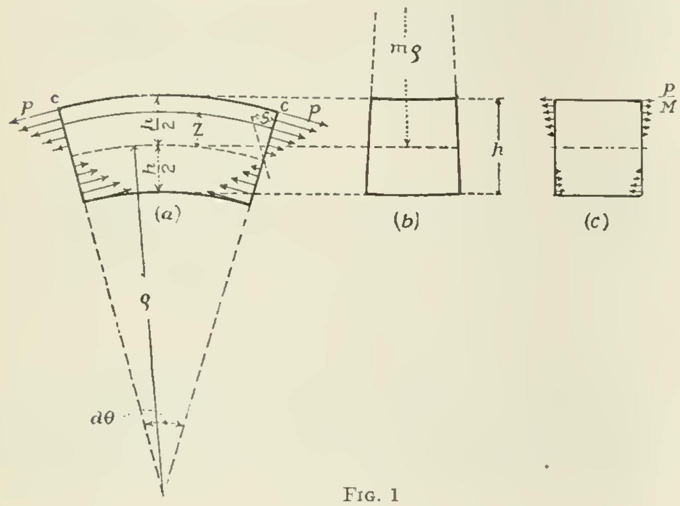

Fig. 1

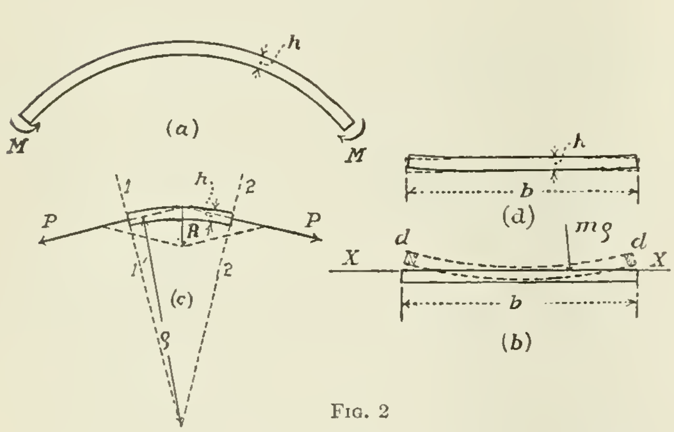

Fig. 2

Since then in the bending of a thin, wide strip the cross-sections (with a negligible distortion at the corners) remain substantially as before, whereas our theory requires a pronounced distortion, it is evident that Equations [2] and [3] should be modified.

Returning to the case of Fig. 1, it is clear that the distortion of the cross-section will be prevented by applying in its plane the forces shown in Fig. 1 (*c*). These forces in turn affect the longitudinal strain. Thus for a fiber *c-c*, Fig. 1 (*a*), the elongation due to the longitudinal stress p alone would be p/E. On this there will be superimposed a contraction due to the stress p/m acting in the plane of the cross-section, and this contraction is—

$$\frac{p}{mE} \times \frac{1}{m} = \frac{p}{m^2E}$$

The total elongation of the fiber *c-c* will therefore be—

$$c = \frac{p}{E} - \frac{p}{m^2E}$$

whence—

$$p = \frac{cEm^2}{m^2 - 1} \qquad [4]$$

Using this value of p in [2], the equation for the elastic line becomes—

$$M = \frac{EI}{\rho} \times \frac{m^2}{m^2 - 1} \qquad [5]$$

This is the formula that should be used in the case of bending thin, wide strips. If we take $m = 10/3$, then—

$$\frac{m^2}{m^2 - 1} = 1.10$$

Hence in experiments on thin strips of comparatively great width, Equation [3] will give a value for E which is about 10 per cent too high.

3 Now Equations [3] and [5] furnish solutions of the problem of bending in two extreme cases. For intermediate cases more detailed consideration of the distortion of the cross-section is necessary. To give the complete theory of these problems would be beyond the scope of the present communication.

For the sake of completeness, however, the writer wishes to state that in the case of a strip acted upon at its terminal cross-sections by equal and opposite bending moments, there is obtained in place of Equations [3] and [5]—

$$M = \frac{EI}{\rho} \times \frac{m^2 - k}{m^2 - 1} \qquad [6]$$

in which the quantity k is a function of the radius ρ, the thickness h, and the width b of the strip. A number of values of k are given in the table below where—

$$\beta b = b\sqrt[4]{\frac{3(m^2 - 1)}{m^2\rho^2h^2}} = 1.286\frac{b}{\sqrt{\rho h}} \qquad [7]$$

$\beta b =$	0.5	1.0	1.5	2.0	2.5	3.0	4.0	5.0	$\beta b > 5$
$k =$	0.999	0.995	0.975	0.877	0.818	0.725	0.534	0.420	$\frac{2}{\beta b}$

For example, for $h = 1$ mm. and $\rho = 500$ mm., we obtain, from [7], $\beta b = 3$; the value of k for $\beta b = 3$, as given in the table, is 0.725. Substituting this value in Equation [6] gives—

$$M = \frac{EI}{\rho} \times \frac{m^2 - 0.725}{m^2 - 1} = \frac{EI}{\rho}(1 + 0.0272)$$

that is, Equation [3] would give a radius of curvature about $2^3/_4$ per cent too large.

The table therefore enables us to estimate in what cases Equation [3] can be used without material error in calculating E from the experiments with strips.

S. Timoshenko.

Philadelphia, Pa.

Work of A.S.M.E Boiler Code Committee

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and simultaneously published in MECHANICAL ENGINEERING.

Below is given the interpretation of the Committee in Case No. 411, as formulated at the meeting of January 9, 1923, and approved by the Council. In accordance with the Committee's practice, the names of inquirers have been omitted.

CASE NO. 411

Inquiry: Par. 212c which permitted increasing the pitch of staybolts on cylindrical surfaces over that required for flat plates, had, about two years ago, been held in abeyance pending the revision of the Boiler Code, but nothing has been left in its place. In view of this, what rules should be followed pending the publication of the revised Code?

Reply: It has been proposed to revise Par. 212c as follows, and the Committee recommends to the state inspectors that this rule be followed in place of the rules now given in Par. 212c of the Code:

Par. 212 *d* For furnaces over 38 in. in outside diameter of vertical fire-tube boilers and other types of furnaces and combustion chambers not covered by special rules in this Code, which have curved sheets subject to external pressure, that is, pressure on the convex side, the staying, both circumferential and longitudinal, shall be provided for in accordance with the following formula:

$$P = \frac{CT^2}{p^2} + 250\frac{T}{R}$$

where p and the value of C are as given in Par. 199, p shall not exceed $2T$, and p^2 shall not exceed $0.008\ CTR$.

The stress per sq. in. in staybolts shall not exceed 7500 lb., based on a total stress obtained by multiplying the product of the circumferential and longitudinal pitches by $\left(P - 250\frac{T}{R}\right)$.

Second Revision of A.S.M.E. Boiler Code, 1923

A HEARING is held by the Boiler Code Committee at least once in four years, at which all interested parties may be heard, in order that such revisions may be made as are found to be desirable, as the state of the art advances. The year 1922 became the period of the second revision and the Boiler Code Committee held a Public Hearing in connection with the recent Annual Meeting of the Society in December, 1922, to which the membership of the Society and everyone interested in the steam-boiler industry was invited to attend and present their views.

For the convenience of every one interested, a printed schedule of the various proposed revisions had been published and distributed to all those who were invited to attend the Public Hearing and the opportunity was given thereat for the most careful consideration of all of the proposed revisions. As a result of the suggestions received at the Public Hearing, a number of modifications of the previously announced revisions were offered and in addition suggestions were received for still further revisions of the Code. All of these suggestions for modifications and new revisions have been carefully considered by the Boiler Code Committee and the result in modifications of revisions and additional revisions are here published.

It is the request of the Committee that these revisions be fully and freely discussed so that it may be possible for anyone to suggest changes before the rules are brought to final form and presented to the Council for approval. Discussions should be mailed to C. W. Obert, Secretary to the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be considered by the Boiler Code Committee.

The revisions here published are limited to the paragraphs appearing in the 1918 Edition of the A.S.M.E. Boiler Code, and the paragraph numbers refer to the paragraphs of similar number in that edition. For the convenience of the reader in studying the revisions, all added matter appears in small capitals and all deleted matter in smaller type in brackets.

Modifications of Revisions

PAR. 9 ADD THE FOLLOWING TO THE REVISED FORM PRINTED IN THE JULY 1922 ISSUE OF MECHANICAL ENGINEERING:

SEAMLESS TUBES OR LAP-WELDED PIPE MAY BE USED FOR DRUMS OR OTHER PRESSURE PARTS OF A BOILER PROVIDED SUCH TUBES OR PIPES CONFORM TO THE SPECIFICATIONS FOR WELDED AND SEAMLESS STEEL AND WROUGHT-IRON PIPE, AND PROVIDED ALSO THAT THE OUTSIDE DIAMETER OF THE TUBES OR PIPES DOES NOT EXCEED 20 IN.

PAR. 19 CANCEL PROPOSED REVISION OF THIS PARAGRAPH PRINTED IN THE DECEMBER 1922 ISSUE OF MECHANICAL ENGINEERING.

PAR. 21 REPLACE REVISED FORM PRINTED IN DECEMBER 1922 ISSUE OF MECHANICAL ENGINEERING WITH THE FOLLOWING:

21 *Tubes for Water-Tube Boilers.* The maximum allowable working pressures for STEEL OR WROUGHT-IRON tubes used in water-tube boilers, shall be for the various diameters and gages measured by Birmingham wire gage, as given in Table 2. REDRAWN PIPE NOT TO EXCEED $1^1/_2$-IN. STANDARD PIPE SIZE WHICH MEETS THE PIPE SPECIFICATIONS, MAY BE USED FOR WATER-TUBE BOILERS FOR A WORKING PRESSURE NOT TO EXCEED 200 LB. PER SQ. IN., WHEN SCREWED IN THE SHEET, PROVIDED THE WALL THICKNESS IS AT LEAST 50 PER CENT GREATER THAN THE WALL THICKNESS REQUIRED BY TABLE 2. THE MAXIMUM ALLOWABLE WORKING PRESSURES FOR COPPER TUBES USED IN WATER-TUBE BOILERS SHALL BE FOR THE VARIOUS DIAMETERS AND GAGES MEASURED BY BIRMINGHAM WIRE GAGE AS GIVEN IN TABLE $2^1/_2$, BUT NOT TO BE USED FOR PRESSURES TO EXCEED 250 LB. COPPER TUBES SHALL NOT BE USED WITH SUPERHEATED STEAM.

TABLE $2^1/_2$ MAXIMUM ALLOWABLE WORKING PRESSURES FOR COPPER TUBES FOR WATER-TUBE BOILERS

For Different Diameters and Gages of Tubes

Outside diam. of tube, in. D	Gage—B. W. G. 12	11	10	9	8	7	6	5	4
2	170	231	250	250	250	250	250	250	250
$3^1/_4$	...	...	101	142	215	250	250	250	250
4	...	...	...	...	128	173	242	250	250
5	...	...	...	...	...	...	143	184	218

$$P = \left(\frac{t - 0.039}{D}\right)12000 - 250$$

Where P = Maximum allowable working pressure, lb. per sq. in.
t = Thickness of tube wall, in.
D = Outside diameter of tube, in.

PAR. 185 ADD THE FOLLOWING TO THE REVISED FORM PRINTED IN THE DECEMBER 1922 ISSUE OF MECHANICAL ENGINEERING:

WHERE PLATES ARE PLANED OR MILLED DOWN IT SHALL BE FOR THE ENTIRE CIRCUMFERENCE OF THE JOINT, AND THE FILLET AT THE EDGE OF THE PLANING SHALL BE NOT LESS THAN 1 IN. RADIUS.

PAR. 194 REVISE PARAGRAPH AS PRINTED IN AUGUST 1922 ISSUE OF MECHANICAL ENGINEERING TO READ AS FOLLOWS:

194 The longitudinal joint of a dome 24 in. or over in inside diameter shall be of butt and double-strap construction or made without a seam of one piece of steel pressed into shape, and its flange shall be double-riveted to the boiler shell. IN THE CASE OF

NOTE:—Matter in caps.—added matter; Matter in smaller type in brackets—to be deleted.

a dome less than 24 in. in diameter, for which the product of the inside diameter and the maximum allowable working pressure does not exceed 4000 in. lb., its flange may be single riveted to the boiler shell and the longitudinal joint may be of the lap type provided it is computed with a factor of safety not less than 8.

When a dome is located on the barrel of a locomotive-type boiler or on the shell of a horizontal-return-tubular boiler, the diameter of the dome shall not exceed six-tenths the diameter of the shell or barrel of the boiler.

All domes shall be so attached that any water which enters the dome along with the steam can drain back into the boiler.

Flanges of domes shall be formed with a corner radius, measured on the inside, of at least twice the thickness of the plate for plates 1 in. thick or less, and at least three times the thickness of the plate for plates over 1 in. in thickness.

When boiler shells are cut to apply steam domes, the net area of metal, after rivet holes are deducted, in flange and liner, if used, must not be less than the area required by these rules for a length of boiler shell equal to the length removed. The height of vertical flange equal to three times the thickness of the flange shall be included in the area of the flange (see pars. 187 and 188).

Par. 195 Note the following on revised form printed in December 1922 issue of Mechanical Engineering:

Insert the word "unstayed" before the word "dished," the first word of the fourth section of this paragraph.

Par. 212*a* Note the following on revised form printed in December 1922 issue of Mechanical Engineering:

Omit the words "except handholes" in the 9th and 16th lines.

Par. 216 Note the following on revised form printed in December 1922 issue of Mechanical Engineering:

Change the figure "1.25" at the beginning of line 11, to "1.5."

Par. 218 Change the first sentence of revised form printed in December 1922 issue of Mechanical Engineering as follows:

218 When stays are required the portion of the heads below the tubes in a horizontal-return-tubular boiler shall be supported at the front head by through stays with nuts inside and outside and at the rear head by attachments which distribute the stress.

Par. 230 Note the following on revised form printed in December 1922 issue of Mechanical Engineering:

Insert the word "determined" after the word "length" in the 9th line.

Par. 231 Note the following on revised form printed in December 1922 issue of Mechanical Engineering:

Insert the words "or rivets" after the word "staybolts" in the 16th line.

Par. 239 Note the following on revised form printed in December 1922 issue of Mechanical Engineering:

Add the words "or flame" to section a-4.

Par. 247 Replace the revised form printed in July 1922 issue of Mechanical Engineering with the following:

247 Where no rules are given and it is impossible to calculate with a reasonable degree of accuracy the strength of a boiler structure or any part thereof, a full-sized sample shall be built by the manufacturer and tested in a manner to be prescribed by the boiler code committee and in the presence of or more representatives appointed to witness such test.

Par. 253 Note the following on revised form printed in December 1922 issue of Mechanical Engineering:

Revise fifth line of the first section to read: Diameter for [thicker] material [not] more than $^5/_{16}$ [$^5/_8$] in. thick.

Insert the word "such" before the first word "holes" in the second section.

Par. 260 Note the following on revised form printed in December 1922 issue of Mechanical Engineering:

Omit the words "when used" in the first line.

In Fig. $20^1/_2$, turn this figure upside down and cross-hatch and revise so that the cross-section of flanged manhole frame will have a curved line representing the lower edge of plate around hole.

Par. 261 Replace the revised form printed in December 1922 issue of Mechanical Engineering with the following:

261 The strength of the rivets in shear on each side of a [manhole] frame or ring reinforcing manholes or other openings such as those cut for steel nozzles and boiler flanges over 3 in. pipe size shall be at least equal to the tensile strength of the maximum amount of the shell plate removed by the opening and rivet holes for the reinforcement on any line parallel to the longitudinal axis of the shell, through the manhole, or other opening.

Par. 268 Revise first section of form printed in December 1922 issue of Mechanical Engineering to read as follows:

268 *Threaded Openings.* All pipe threads shall conform to the American Pipe Standard and all connections 1 in. pipe size or over shall have not less than the number of threads given in Table 8. For smaller pipe connections there shall be at least four threads in the opening.

Par. 269 Revise first sentence of form printed in December 1922 issue of Mechanical Engineering to read as follows:

269 *Safety Valve Requirements.* Each boiler having more than 500 sq. ft. of water heating surface or in which the generating capacity exceeds 2000 lb. per hour, shall have two or more safety valves.

Par. 273 Note the following on revised form printed in December 1922 issue of Mechanical Engineering:

Replace the word "body" in the 4th and 5th lines with the word "casing."

Par. 274 Revise first section of form printed in December 1922 issue of Mechanical Engineering as follows:

274 The minimum aggregate [total] relieving capacity of all of the safety valve or valves required in a boiler shall be not less than that determined on the basis of 6 lb. of steam per hour per sq. ft. of boiler heating surface for water-tube boilers. For all other types of power boilers, the total relieving capacity shall be not less than that determined on the basis of 5 lb. of steam per hour per sq. ft. of boiler heating surface, for boilers with maximum allowable working pressure above 100 lb. and on the basis of 3 lb. of steam per hour per sq. ft. of boiler heating surface for boilers with maximum allowable working pressures at or below 100 lb. per sq. in. In many cases a greater relieving capacity of safety valves will have to be provided than the minimum specified by this rule and in every case the requirement of par. 270 shall hold.

Revise added matter at end of second section as follows:

Where the operating conditions are changed, the safety valve capacity shall be increased, if necessary, to meet the new conditions and be in accordance with Par. 270.

Par. 278 Revise added matter of form printed in December 1922 issue of Mechanical Engineering as follows:

Each valve shall have an open drain through the casing below the level of the valve seat. For valves exceeding 2 in. pipe size, the holes shall be tapped for drip pipe. In the case of fire-tube boilers, the boiler openings for safety valves shall be not less than those corresponding to an evaporation of 5 lb. of steam per hour per sq. ft. of heating surface and to safety valves having the intermediate lifts and corresponding relieving capacities given in table 15.

Par. 280 Revise last line of form printed in December 1922 issue of Mechanical Engineering as follows:

diameters of [all of] the safety valve connections and shall also meet the requirements of par. 278.

Par. 281 Revise second sentence of form printed in December 1922 issue of Mechanical Engineering as follows:

To close after blowing down not more than 4 per cent of the set pressure, except for working pressures of 50 lb. per sq. in. or less, in which case the blow down shall not exceed 2 lb. per sq. in.

Par. 287 Note the following on revised form printed in December 1922 issue of Mechanical Engineering:

Replace the word "body" in the first line, with the word "casing."

Par. 289 Revise second line on revised form printed in December 1922 issue of Mechanical Engineering as follows:

heated steam, shall have a casing of steel, steel alloy, or equivalent heat-resisting material, including all parts which

Insert the words "(see Par. 12)" after the word "outlet" at the end of the third line, ending the sentence. Begin new sentence with the words the valve shall have a flanged, etc.

Par. 321 Add the following sentence to form printed in December 1922 issue of Mechanical Engineering:

For steam pressures of 200 lb. and over, the water connections shall be of steel pipe or tubing, wrought-iron pipe or the equivalent.

Par. 324 Note the following on revised form printed in December 1922 issue of Mechanical Engineering:

Insert the word "or" before the word "over" in the second line.

Par. 332 Replace the revised form printed in December 1922 issue of Mechanical Engineering with the following:

332 Each boiler shall conform in every detail to these Rules, and shall be distinctly stamped with the symbol as shown in Fig. 23, denoting that the boiler was constructed in accordance therewith.

After obtaining the stamp to be used when boilers are to be constructed to conform with the A.S.M.E. Boiler Code, a state inspector, municipal inspector, or an inspector employed regularly by an insurance company which is authorized to do a boiler insurance business in the state in which the boiler is built and in the state in which it is to be used, if known, is to be notified that an inspection is to be made and he shall inspect such boilers during construction and after completion. At least two inspections shall be made, one before reaming rivet holes and one at the hydrostatic test. In stamping the boiler after completion, if built in compliance with the code, the builder shall stamp the boiler in the presence of the inspector, after the hydrostatic test, with the A.S.M.E. Code stamp, the builder's name and the serial number of the manufacturer. A data sheet shall be filled out and signed by the manufacturer and the inspector. This data sheet together with the stamp on the boiler shall denote that it was constructed in accordance with the A.S.M.E. Boiler Code.

In cases where boilers cannot be completed and hydrostatically tested before shipment, the proper stampings shall be applied at the shop and two data sheets signed as herein provided by the same or different inspectors covering the portions of the inspections made at the shop and in the field, the data sheets each to be separately sent to the proper destination.

Each boiler shall be stamped adjacent to the symbol as shown in Fig. 24, with the following items with intervals of about one-half inch between the lines:

1 Registered number

2 A.S.M.E. [Manufacturer's] serial number which may be the manufacturer's serial number.

[2 State in which boiler is to be used.]

[3 Manufacturer's State standard number.]

3 Name of manufacturer.

4 Maximum working pressure when built.

5 Water heating surface in sq. ft.

[5 State's number.]

6 Year put in service.

Items 1, 2, 3, 4, and 5 to be stamped at the shop where built.

Item 6 is to be stamped by the proper authority at point of installation.

Portable boilers of 100 hp. or less shall have the stampings as herein provided applied on a non-ferrous plate 3 in. x 4 in. size which shall be, as nearly as practicable, irremovably fastened to the boiler near the water-column connections. All other boilers may have the stampings so applied or they may be applied directly to the boiler structure.

Manufacturers, before using the A.S.M.E. symbol, shall be given a registration number by The American Society of Mechanical Engineers. This number shall be stamped directly on the boiler or placed on a non-ferrous plate. The registration number shall be placed not more than one-half inch above the symbol and centering on it. Inspection jurisdictions shall be furnished by the A.S.M.E. a list of registered manufacturers, with the corresponding registration numbers issued.

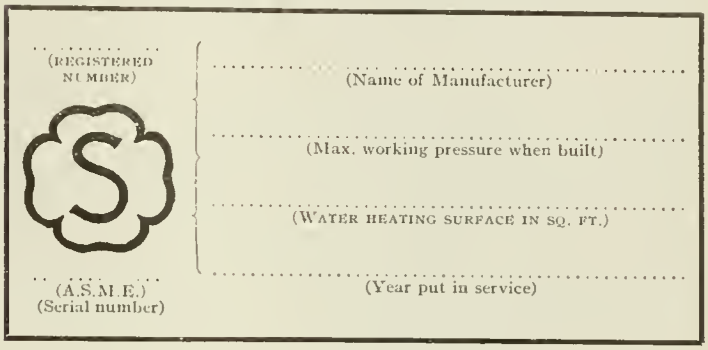

Fig. 24 Form of Stamping

Par. 429 Omit revision in form printed in December 1922 issue of Mechanical Engineering.

New Revisions of A.S.M.E. Boiler Code, 1923

Par. 22 Revised:

22 *Tubes for Fire-Tube Boilers.* The minimum thickness of tubes used in fire-tube boilers measured by Birmingham wire gage, for maximum allowable working pressures not exceeding 175 lb. per sq. in., shall be as follows:

	Gage—B. W. G.	
	Steel or Wrought Iron	Copper
Diameters 1 in. or over, but less than $2^1/_2$ in.	13	10
Diameter $2^1/_2$ in. or over, but less than $3^1/_4$ in.	12	8
Diameter $3^1/_4$ in. or over, but less than 4 in.	11	7
Diameter 4 in. or over, but less than 5 in.	10	6
Diameter 5 in.	9	5

For each increase of one gage in thickness above that shown in the table, the maximum allowable working pressure will be increased by 200 lb. divided by the diameter of the tube in inches.

Copper tubes shall not be used for pressures in excess of 250 lb. per sq. in.

Copper-tube specifications: Specifications for seamless copper boiler tubes will be included following those of the American Society for Testing Materials, serial designation b 13–18.

Par. 179 Revised:

179 *Maximum Allowable Working Pressure.* The maximum allowable working pressure is that (at which a boiler may be operated as) determined by employing the factors of safety, stresses, and dimensions designated in these Rules.

(Remainder of paragraph unchanged)

Par. 333*c* Revised:

c On traction, portable or stationary boilers of the locomotive type or Star water-tube boilers—on the furnace end, above the handhole. Or on traction boilers of the locomotive type—on the left wrapper sheet forward of the driving wheel.

(*Continued on page 273*)

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities Papers and Proceedings of

The American Society of Mechanical Engineers

29 West 39th Street, New York

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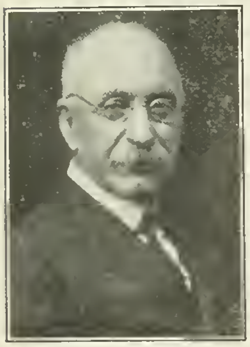
Plain Speaking



Dr. Ira N. Hollis

"BROTHERHOOD of all engineers and their united action in any service that will be for the good of our country." This motto, worthy and characteristic of Dr. Ira N. Hollis, the 1917 President of The American Society of Mechanical Engineers, appeared in the volume of Transactions for that year, during which he took his place as first chairman of the Engineering Council, an important first step toward the national coöperation of engineering societies. Dr. Hollis' life has been given to the ideal of service: he realizes the need for straightforward engineering thought in our modern civilization, and he has confidence in the ability of the engineering profession to perceive this need and adapt itself for it. However, he believes that facts must be faced, and in a recent communication he directs our attention to the purposes of The Federated American Engineering Societies. We are privileged to print below a portion of this letter. Read it carefully.

"The plain truth is that the engineers have not yet come to an understanding of themselves. In their own minds they have not yet passed out of that classification that the public has given them, namely, of being technical men called in to advise only on technical questions. A few of them have passed out of that category in the esteem of the public, but the rank and file are still laboring under the disadvantage of being simply hired men. One may well wonder how long this is to continue. We know perfectly well that we all ought to be good citizens and that we ought to have our share in the government of nation and city. That does not at all mean neglecting our professions, but it does mean giving some time and some money toward wielding our own proper influence.

"The Federated American Engineering Societies was organized as a kind of senate wherein would appear public questions. It sprang out of the old Engineering Council where the four oldest national societies got together on certain things that are common to all in order that they might not have to present a too great variety of opinions or decisions. The old Council was really the outcome of an effort to work together. This new society, which takes in local and national societies alike, holds out a prospect of bringing the engineer before the public as nothing else ever has. If it did absolutely nothing else than to teach the American people the value of the engineering profession and capacity of its members to assist in the decision of great national problems, it would justify itself. The main difficulty is found in its support. Few engineers are opposed to it in principle, but there are altogether too many who do not care to put in even the small amount of dues now required. Some societies find the total amount paid over by them a burden and fear to lose their own members by diverting any part of their income to this activity. It is unenlightened in men to demand immediate personal benefit from the payment of a small amount, \$1.00 or \$1.50 per year, for the support of this public institution. They might as well ask for some immediate personal benefit springing out of their taxes paid over to the state and Government. We all get a benefit from the taxes, but not all alike. The man who pays a thousand dollars gets only just what the man who pays ten dollars gets. We pay willingly because our taxes mean the maintenance of society. The case of the F.A.E.S. payment is the same as any public assessment. The engineer has been the hired man of the ages. He is found from time to time in the historic period. Upon him the Egyptians depended for the life of the population in the Nile Valley. The same is true in the valley of the Euphrates and the Tigris. Wherever he has been absent, the nation has gone steadily down hill, and yet he has, up to within a comparatively recent period, had little consideration from the general public simply because he has had a tendency to treat himself as purely a technical man. There is only one way to recover from that in our modern days, and that is by organization. We know it. There must be a thousand other associations or organizations in the United States for different purposes, and we cannot afford to become ineffective in that direction. The Federated Societies, or something like them, offer us the only means of making the profession well known in its larger possibilities."

Safe Engineering Versus Safety Engineering

Champlain Studios, N. Y.

Wm. J. Venning

EVER SINCE the earliest ages man has been forced to provide means for self-protection. Primitive man fashioned cudgels from stone which he used as weapons of defense as well as offense, and for aid in self-preservation lived in groups with his fellow-beings. As these groups grew in size and men were compelled to depend upon one another for protection of the group as a whole, it became necessary to make laws defining the conduct of the individual. Some of these laws the present-day safety engineer would call strictly "safety-first" laws. For instance, in the Bible, the eighth verse of the 22nd chapter of Deuteronomy specifically interprets a building law; then again King Hamurabi, whose death occurred in Babylon in the year of 2185 B.C., promulgated a building law as follows: "If a builder build a house for a man and do not make its construction firm, that builder shall be put to death." And so on down through the ages to our present safety codes.

The need for a safety code is usually determined by a study of accident causes, and since industrial development has been so rapid, what was considered a good code yesterday is obsolete today. Then again, the lack of uniformity and agreement between the various states has always been an insurmountable obstacle.

"Safe Engineering" takes into consideration not only safety factors in design and construction but should also provide for safe operation or use. "Safety Engineering" is applied where design and construction have failed to provide for safety operation or use. That it would be much cheaper to always incorporate safe engineering in construction and design cannot be gainsaid. Fifty machines of the same design, made by the same builder, sold to fifty different users, if not properly guarded during construction, will eventually be guarded fifty different ways by the purchasers with varying degrees of efficiency and cost strictly in accordance with the purchaser's state of mind. Where it has been the writer's task to initiate the uninformed industrial plant owner into the realm

of safety by offering certain recommendations for safeguards as a result of plant inspection, one of the first questions asked is, "Why doesn't the manufacturer properly guard the machine when he constructs it?"

There are three important points to be considered in the safeguarding of machinery:

1 Drive belts and pulleys or drive device
2 Moving and reciprocating parts
3 Point of operation.

The drive belts or device of any machine are easily guarded, the most efficient construction being of expanded metal, perforated metal, or woven wire, mounted on an angle-iron frame of the box type and securely fastened in place. Guards of this type will stand hard usage and repay for their cost in reduced insurance rates.

To guard the moving and reciprocating parts invariably requires a little more thought. Solid guards made of sheet iron are usually employed, although for quantity production on similar-type machines a cast guard made from a pattern is the least expensive. The installation of these guards must permit of easy machine adjustment and in no way interfere with efficient operation.

The point of operation of a machine is that part where the stock is fed in. Automatic feeds with the moving parts guarded and which remove the hazards inherent in hand feeding are most desirable. Where hand feeding is necessary, the guard should fully protect the operator and expedite the work. Although the machine designer and builder can easily guard the drive device and moving parts of any machine during initial construction and can do it much cheaper than the purchaser because the work is done on a production basis, he cannot always guard the point of operation because of the many and various kinds of work performed on the same machine; for instance, a gate guard that would be practical on a punch press for second-operation hand-fed work, would not do for blanking work from strip stock. Particularly in small shops with limited mechanical equipment does the safety engineer meet with this difficult problem. However, closer coöperation between the machine builder and the professional safety engineer should gradually solve this problem, and teaching safety engineering in the technical schools and engineering colleges should eventually make "Safe Engineering" the principal factor in design and construction.

In every instance sound engineering practice should be followed to obtain the best results.

An efficiently guarded machine will give the operator a greater sense of security, thereby removing the necessity of continual caution.

Guarding prevents property damage often caused by careless handling of stock around and near machinery in motion.

Well-guarded machines permit the piling of stock close up to the machine and conserve floor space.

A machine properly guarded makes it possible to use unskilled labor on many operations that would otherwise call for skilled labor, because part of the skill or training consists in being able to localize and avoid the hazard.

Efficient machine guarding reduces labor turnover by keeping the worker on the job uninjured, thereby increasing production through increased shop efficiency.

William J. Venning.[1]

Asiatic Markets for Industrial Machinery

FOR YEARS there has been a not unfounded complaint to the effect that the American exporter does not receive the same amount of support from his government as do his competitors from theirs. In particular, attention was called to the excellent information service maintained for the export trade before the war by the British and German governments.

That this situation is rapidly changing for the better is well indicated, for example, by a recent publication of the Bureau of Foreign and Domestic Commerce of the Department of Commerce, entitled Asiatic Markets for Industrial Machinery, by Walter H. Rastall, Mem. A.S.M.E.

This book is a veritable repository of information not only on the actual export statistics but on conditions surrounding the business of exporters of industrial machinery to Asiatic markets, their purchasing power and requirements. The investigation deals primarily with machinery used in and about factories and power plants, but also includes data on construction machinery, mining machinery and certain other types—not, however, such special machinery as cash registers, automobiles and sewing machines. In addition to the more obvious features of such an investigation, an effort has been made to examine into the advertising, financing, and selling methods employed by foreign competitors as well as by successful American exporters, and certain sections of the report have been prepared with the idea of furnishing detailed information needed by men who are starting in export work as well as those with more ample experience.

In the letter of submittal of the Director of the Bureau to Secretary of Commerce Hoover, it is pointed out that a notable movement toward industrialization is in progress in the more important Asiatic countries, and Mr. Rastall is decidedly optimistic with regard to the prospects for development. Considering that the total population of the countries covered by this report is probably well in excess of half a billion souls and that they have large natural resources still awaiting development, the subject of these markets for American machinery is one well worthy of serious attention.

[1] President, American Society of Safety Engineers.

Montreal Spring Meeting

THE coming Montreal Spring Meeting of The American Society of Mechanical Engineers is the first to be held outside of the borders of the country since 1894, when one was also held in Montreal. It is hoped that the coming convention, May 28–31, will afford an excellent opportunity for the development of the already amicable relations between the engineers of Canada and the United States. The members of the Engineering Institute of Canada have been invited to attend, and the Montreal Branch of the Canadian Institute is coöperating wholeheartedly in the plans for the meeting.

The technical program will of course stress Hydroelectric Development, and two sessions will be devoted to that subject. The other topics to be considered are Management Engineering, with special application to the Paper and Pulp Industry, Port Development, in which the harbor problems of Montreal will be treated; Textiles; Railroads; and Fuels. The Professional Divisions on Power, Management, Materials Handling, Textiles, Railroads, and Fuels are coöperating in these sessions and the Divisions on Aeronautics, Forest Products, and Machine Shop Practice are presenting papers for the miscellaneous sessions.

The meeting will be notable for its entertainment features which will comprise a smoking concert at which members of the A.S.M.E. will be the guests of the Montreal branch of the Engineering Institute of Canada, a dinner dance, and excursions to points of scenic and engineering interest in and around Montreal. The number of points to be visited make Montreal an exceptionally attractive convention city. Following the meeting a trip to Grandmere and Quebec is being planned.

Detailed information will be found in the current issues of *A.S.M.E. News* and the tentative program for the meeting will appear in the April 7 issue.

Bureau of Standards Report on Welded Vessels to Come Later

THE complete report on the Bureau of Standards investigations on welded pressure vessels which was promised in the March issue of Mechanical Engineering, page 210, has not as yet been received by the A.S.M.E. Boiler Code Committee and its presentation will necessarily be deferred to a later issue. It is hoped that it will be possible to present a comprehensive report on this most interesting and valuable series of tests.

Erratum

IN extracts from the U.E.S. treasurer's report for 1922, printed in the March issue of Mechanical Engineering, page 205, the cash on hand as of December 31, 1922 was inadvertently stated as amounting to $138,294.27. The figure should have been $32,754.89.

Dr. M. A. Hunter Presents Facts About High-Temperature Alloys at Newark Meeting

THE requirements of electric heaters, valves for internal-combustion engines, containers for high-temperature furnace work and parts of steam boilers for use with high superheats have made the subject of high-temperature alloys of great interest to mechanical engineers. The Metropolitan Section of the A.S.M.E. held a meeting on this subject in Newark on February 13 which was addressed by Dr. M. A. Hunter, professor of electrochemistry at Rensselaer Polytechnic Institute. Dr. Hunter presented many facts which are of importance to those engaged in work of the nature mentioned.

The line between high- and low-temperature alloys may be roughly drawn at around 1800 deg. fahr., although not all metals or alloys melting above this temperature can be used, either for technical or commercial reasons. Thus the metals of the platinum groups are too rare and costly, at least for large-scale applications, although used extensively for high-temperature chemical work and pyrometry. Metals like tungsten, tantalum, and molybdenum are chemically unstable when exposed to air, but can be used as in gas-filled electric lamps at extremely high temperature under proper conditions.

The most common metals available for high-temperature commercial work in air or active gases are iron, melting at 1520 deg. cent.; chromium, at 1550 deg.; cobalt, at 1590 deg.; nickel, at 1450 deg.; silicon, at 1420 deg.; manganese, at 1225 deg.; and copper, at 1084 deg. These are the chief constituents of high-temperature alloys, which, however, may contain other metals, such as tungsten, in small quantities.

In general, high-temperature alloys consist of two or three components united in what metallurgists call a "solid solution."

High-temperature alloys may be subjected to the action of high temperature alone or in combination with chemical actions—of which the most important are those of a corrosive nature—and mechanical stresses, and alloys good for one purpose may not be suitable for another. For temperatures below 700 deg. cent., particularly where chemical attack is to be feared (except in the case of nitric acid), copper-nickel mixtures form an important class. Of this the best known is monel metal, an alloy of about 30 per cent copper and 70 per cent nickel. Its melting point is said to be 2480 deg. fahr. Monel metal may be used in the form of castings, rolled sheets, and drawn wire. Its strength approaches that of mild steel in corresponding products. At temperatures above 700 deg. cent. it is apt to oxidize. Cast monel metal usually has a high silicon and low manganese content, as this helps the fluidity of the metal; rolled or drawn monel is low in silicon and high in manganese.

An alloy consisting of 40 per cent nickel and 60 per cent copper, known as "Advance wire," is of considerable value in temperature-measurement work as it has a zero temperature coefficient over a range of 300 deg.

Some of the valuable high-temperature alloys are characterized by the presence of chromium in considerable degree. The earliest of those developed commercially were the nickel-chrome alloys which have found extensive application as electrical resistance wire and heating elements for electric stoves and the like. The most used combination is 80 per cent nickel and 20 per cent chromium. This alloy is noteworthy chiefly for its ability to withstand oxidation at high temperatures. Alloys with practically any proportion of chromium can be formed by casting, but where the metal has to be worked the percentage of chromium should not exceed 20 per cent. The matter of carbon content has to be watched in this alloy with extreme care. The nickel-chromium wire patents are understood to have expired in February of the current year.

Alloys of nickel, iron, and chromium are used for applications where temperatures not exceeding 900 deg. cent. prevail. The alloy nichrome (containing 26 per cent iron, 12 per cent chromium, the remainder nickel and impurities) is used as rod, strip, or wire in electrical resistors. As a cast material it finds increasing applications in carbonizing boxes, retorts, lead and cyanide pots, etc. These alloys do not carburize at high temperatures, crack, warp, or scale, and except under high sulphur conditions in the fuel used, give very satisfactory service. One of their remarkable properties is the ability to retain a considerable proportion of their original strength at 1000 deg. cent., which is very different from the behavior of steel and similar alloys.

Nichrome exhibits great tensile strength at high temperatures. At 1000 deg. cent., material which at room temperature shows 67,000 lb. strength has 12,000 lb. strength, an elongation of 55 per cent, and a reduction in area of 15 per cent. This same metal at 850 deg. cent. has an ultimate strength of 20,000 lb., and at 600 deg. cent. 44,000 lb. It has been successfully used for internal-combustion-engine valves.

Other high-temperature alloys deserving consideration for commercial work are those of the chrome-iron group. These contain chromium in varying percentages from about 20 up to 35 or even 40 and are remarkable for their high resistance both to temperature and to chemical stresses. The physical properties of the chrome-iron alloys (which, of course, differ basically from cast nichrome in that they contain no nickel) are essentially determined by their carbon content, alloys with carbon content below 0.30 per cent machining practically as freely as cold-rolled steel; with carbon content between 0.30 to 1.5 the machining becomes increasingly difficult, and finally, when the 1.5 per cent carbon limit has been reached a material is obtained which casts very well but cannot be machined by ordinary means.

In the discussion which followed, the question was raised as to whether these high-temperature alloys would withstand the combination of temperatures up to 1200 deg. fahr. with pressures such as are encountered, for example, in oil-cracking stills (Burton and Rittman processes). In this connection, it might be mentioned that in France an alloy has been developed of practically the same composition as cast nichrome but with the addition of about 2 per cent tungsten, and that tubes cast of this material have been used in the Claude ammonia process where both high temperatures and high pressures are used simultaneously.

David A. Decrow Dies

DAVID A. DECROW, manager of the water-works department of the Worthington Pump & Machinery Corporation, New York City, died on February 15, 1923. Mr. Decrow was born in Bangor, Me., in 1858, where he received his early education. He was graduated from the University of Maine, College of Mechanic Arts, with the class of 1879.

In the early eighties he became associated with the Holly Manufacturing Co., Lockport, N. Y. His promotions with this company were rapid; in 1893 he was made designing engineer, in 1900 chief engineer, and in 1903 secretary of the firm.

Some years ago the Holly Manufacturing Co. was combined with the Snow Steam Works at Buffalo, N. Y., as part of the International Steam Pump Co., and at that time Mr. Decrow went to Buffalo to take charge of the pumping machinery manufactured by both companies. In April, 1916, the International Steam Pump Co. was succeeded by the Worthington Pump & Machinery Corporation. Soon after this Mr. Decrow was called to the New York office to become manager of the water-works department, the position he held until his death.

Mr. Decrow was active as a member and recently as chairman of the A.S.M.E. Committee on the Test Code for Reciprocating Displacement Pumps. He was a member of a number of clubs and organizations in Buffalo.

Engineering Division, National Research Council, Elects Officers

DR. F. B. JEWETT, vice-president of the Western Electric Company, New York N. Y., has been elected chairman of the Engineering Division of the National Research Council, to succeed Alfred D. Flinn, who resigned that office last year to become director of Engineering Foundation.

E. B. Craft, chief engineer of the Western Electric Company, was elected vice-chairman of the Division, and M. Holland, formerly of the U. S. Air Service, McCook Field, Dayton, Ohio, appointed director. G. H. Clevenger was reëlected a vice-chairman and W. Spraragen secretary.

Philadelphia Holds Successful Machine Meeting

Technical, Historical, and Economic Phases of Machine Tools and Machine-Shop Practice Discussed Before Large Gatherings. Dean Dexter S. Kimball, President John Lyle Harrington of A.S.M.E., and E. F. DuBrul among the Speakers

TECHNICAL, historical, and economic phases of the machine-tool industry and machine-shop practice were presented and discussed at the Conference on Machine Tools which was held in Philadelphia on February 27 under the auspices of the Engineers' Club of Philadelphia and the Philadelphia Sections of The American Society of Mechanical Engineers and the American Institute of Electrical Engineers, and with the coöperation of the Machine Shop Practice Division of The American Society of Mechanical Engineers.

Over three hundred attended the sessions and dinner, and the good papers, interesting discussion, and increased fellowship among the engineers in machine-shop practice which resulted from the meeting form an achievement of which the Philadelphia engineers may well be proud.

Two sessions were held, the afternoon session being given over to the presentation and discussion of technical papers, the first of which, on the Effect of Variations in Design of Milling Cutters on Power Requirements and Capacity, by Prof. James A. Hall, of Brown University, and Benjamin P. Graves, of the Brown & Sharpe Mfg. Co., appeared in the March issue of MECHANICAL ENGINEERING. The discussion is given later in this account of the meeting. The second paper, on the Design and Construction of Large Machine Tools, by George H. Benzon, Jr., of William Sellers & Co., appears as the leading article of this issue. Charles Penrose, chairman of the Philadelphia Section of the A.S.M.E., was introduced as presiding officer by Dr. Robert H. Fernald, president of the Engineers' Club of Philadelphia. Mr. Penrose called on Frank O. Hoagland, of Worcester, Mass., chairman of the Machine Shop Practice Division of the A.S.M.E., who told of the plans of his Division in meetings, research, and standardization.

Dinner was served at the Engineers' Club and was followed by a brief talk by President John Lyle Harrington of The American Society of Mechanical Engineers, who outlined the steps in the development of modern equipment for industry and transportation. Dean Dexter S. Kimball of Cornell University, past-president of the A.S.M.E., followed with a lantern-slide talk on the History of the Machine Tool and Its Effect on Present-Day Civilization. He elaborated somewhat on the paper which appeared in the March issue of MECHANICAL ENGINEERING and his picturesque portrayal of the romance of mechanical development held the interest of those who filled the seats of the auditorium and a large number who stood throughout his talk. He was followed by Ernest F. DuBrul, general manager of the National Machine Tool Builders' Association, who spoke on the Economic Features of the Machine-Tool Industry. Mr. DuBrul's paper appeared as the leading article in the March issue of MECHANICAL ENGINEERING. Ross B. Mateer, secretary of the Philadelphia Section of the A.I.E.E., presided at this evening session.

Discussion at Afternoon Session

Following the presentation of the paper on Effect of Variations in Design of Milling Cutters on Power Requirements and Capacity by Professor Hall and Mr. Graves, written discussion by Fred A. Parsons[1] was presented. Mr. Parsons took exception to the use of the terms "feed per tooth" or "maximum chip thickness" as bases for the comparison of cutting tools. He favored "average thickness of chip" as a satisfactory basis as it eliminated differences in depth of cut, diameter of cutter, and type of tool. He agreed with the conclusions of the authors in regard to the superiority of coarse-tooth cutters for general purposes.

W. A. Knight[2] stated as his opinion that spiral face milling for large flat-surface work should be obsolete as the cutting edge of a milling cutter must ride the surface every time a cut is taken and the cut is comparatively short.

[1] Kearney & Trecker Corp., Milwaukee, Wis. Mem. A.S.M.E.

[2] Acting-Director Industrial Arts Dept., Ohio State University. Mem. A.S.M.E.

R. Poliakoff[1] submitted a written discussion descriptive of a milling-machine dynamometer. He also pointed out that the end thrust found when using spiral cutters could be overcome by making the cutters with one-half having a right-hand spiral and the other half a left-hand spiral. He agreed with the authors that a 10-in. rake angle is desirable.

Carl G. Barth[2] agreed with the findings of the authors in the advantages of milling cutters with few teeth. He expressed the desire for further experimentation to discover the value of the exponent n in the formula P = constant $\times\, wf^n$ for the pressure on the lathe slicing or cutting-off tool taking a cut w with a feed f. Mr. Barth gave his derivation of an expression for horsepower consumption per cubic inch of metal removed with milling cutters as follows:

$$\mathrm{HP}_c = \text{constant}\ (N/F)^{1-n}\ (D/H)^{1/4}$$

in which N = number of teeth in cutter, F = feed per revolution, H = depth of cut and D = diameter of cutter, and which thus shows that HP_c increases with the number of teeth and decreases with feed per revolution, both raised to the power $(1-n)$; and increases with diameter of cutter and decreases with depth of cut, both raised to the power $^1/_4$; and that this is because the increased diameter reduces while increased depth of cut increases the chip thickness.

John Airey[3] presented a lengthy oral discussion in which he decried the fact that so little effort had been put into research work in machine-shop practice. He agreed with the authors on the subject of rake and lack of consistency of material. He disagreed in the manner of measuring the power consumption and in ascribing some parts of the power loss to the cutter. He gave some of the information previously presented in the paper on the Art of Milling, presented jointly with Carl J. Oxford at the 1921 Annual Meeting of the A.S.M.E., and reiterated the statement made in that paper that the sole criterion of the efficiency with which metal can be removed was the maximum chip thickness for any given material. The spacing of the teeth of the diameter of the cutter had nothing to do with this.

Carl J. Oxford[4] congratulated the authors on presenting scientific facts about an obscure subject. He expressed disappointment, however, because of the narrowness of scope of the research, and the authors' attempt to draw general conclusions from an unquestionably special case, mild steel, one size of milling cutter, and one type of cut only being used. While mild steel could be successfully milled at a speed in excess of 120 ft. per min., high-machineability alloy steels could seldom be milled at a speed higher than 50 ft. per min., although the chip thicknesses of from 0.006 in. to 0.010 in. per tooth might be the same as for mild steel. Productivity of a given size of milling cutter was in direct proportion to the number of teeth in that cutter and the limiting factors for numbers of teeth were:

1 Rigidity of the machine and holding devices

2 Depth or width of cut and the ability of the machine to deliver power to the cutter

3 Structural strength of the cutter.

In discussing Mr. Benzon's paper on the Design of Large Machine Tools, L. R. Meisenhelter[5] pointed out as three important factors in modern large-machine-tool design the importance of the quality and design of gears, the need for centralized control, and the development of proper lubrication.

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[2] Consulting Engineer, Philadelphia, Pa. Mem. A.S.M.E.

[3] Prof. Engrg. Mechanics, University of Michigan. Mem. A.S.M.E.

[4] Chief Engineer, National Twist Drill & Tool Co., Detroit, Mich. Assoc-Mem. A.S.M.E.

[5] Mechanical Engineer, Philadelphia, Pa. Assoc-Mem. A.S.M.E.

Engineering and Industrial Standardization

New Plan for Financing Industrial Standardization Is Approved

A NEW plan for financing the industrial standardization work of the United States, which provides for membership dues on the basis of one cent per $1000 of gross receipts, has been formally approved by the Executive Committee of the American Engineering Standards Committee. Twenty of the most influential industrial executives of the country have accepted places on an Advisory Committee which will coöperate with the Ways and Means Committee in the refinancing of the American Engineering Standards Committee.

This report announces a new class of members in the A.E.S.C. to be known as "sustaining members," and provides for them a special service, including information bulletins on developments in standardization work in this country and in every other country where industrial standardization is in progress.

The newly created Advisory Committee of the A.E.S.C. consists of the following men:

W. H. Barr, President, National Founders' Association, Chicago, Ill.
A W. Berresford, General Manager, Cutler-Hammer Company, Milwaukee, Wis.
L. F. Butler, President, Travelers Insurance Company, Hartford, Conn.
Wm. Butterworth, President, Deere and Company, Moline, Ill.
John J. Carty, Vice-President, American Telephone and Telegraph Company, New York, N. Y.
W. W. Coleman, President, Bucyrus Company, South Milwaukee, Wis.
G. B. Cortelyou, President, Consolidated Gas Company, New York, N. Y.
J. K. Cullen, President, Niles-Bement-Pond Company, New York City
J. E. Edgerton, President, National Association of Manufacturers, New York, N. Y.
John R. Freeman, Consulting Engineer, Providence, R. I.
E. M. Herr, President, Westinghouse Electric and Manufacturing Co., East Pittsburgh, Pa.
Charles E. Hodges, President, American Mutual Liability Insurance Company, Boston, Mass.
Sidney J. Jennings, President, U. S. Smelting, Refining and Mining Company, New York, N. Y.
J. W. Lieb, Vice-President, New York Edison Company, New York. N. Y.
John B. Morton, President, National Board of Fire Underwriters, Philadelphia, Pa.
Dr. Chas. L. Reese, Chemical Director, E. I. du Pont de Nemours and Company, Wilmington, Del.
E. W. Rice, Jr., Honorary Chairman of the Board, General Electric Company, Schenectady, New York.
Henry D. Sharpe, Treasurer, Brown and Sharpe Manufacturing Company, Providence, R. I.
S. W. Stratton, President, Mass. Institute of Technology, Cambridge, Mass.
Ernest T. Trigg, President, John Lucas and Company, Inc., Philadelphia, Pa.

The American Engineering Standards Committee, which was organized in 1918, has heretofore been financed entirely by dues from the nine technical societies and seventeen national trade associations which with seven departments of the Federal Government constitute its present membership. Annual deficits have been cleared by contributions from individual corporations.

It is expected that the new plan of financing will provide an annual budget of $50,000 for the Standards Committee. As this sum is to be realized from sustaining-membership dues amounting to one-thousandth of one per cent of gross receipts, the total of $50,000 would be spread over industries with aggregate gross annual receipts of five billion dollars. For firms which for any reason prefer to subscribe on the basis of capital rather than gross annual receipts, the recommended basis is one and one-half cents per thousand dollars of aggregate market value of the corporate securities of the firm.

The plan calls for the appointment of an engineer-translator who will provide translations of standards developed in foreign countries for the information service to sustaining members. The new information service will be an elaboration of the work which the A.E.S.C. has been carrying on in a small way, in calling to the attention of coöperating bodies and the technical press the important developments in standardization work, foreign as well as American.

The Ways and Means Committee which drew up this plan of financing consisted of the following members:

Albert W. Whitney, Associate General Manager, National Bureau of Casualty and Surety Underwriters.
A. Cressy Morrison, Vice-President, Compressed Gas Manufacturers Association.
W. W. Nichols, Assistant to the President, Allis-Chalmers Manufacturing Company, and President, Electrical Manufacturers Club.
Frank W. Smith, Vice-President, The United Electric Light & Power Company, and President, National Electric Light Association.

Recent Progress of Some Sectional Committees

Standardization of Shafting. Though this Committee has held no meeting since that of December 5, 1922, it has been by no means inactive. The Sub-Committee headed by Prof. A. H. Beyer has held monthly meetings and is well along toward the completion of Part 2 of its report, namely, the Technique of Shafting Design.

Sub-Committee No. 1, of which Louis W. Williams is chairman, has drafted and circulated a questionnaire to approximately 260 dealers and manufacturers in an effort to ascertain which stock lengths of shafting are preferred. With this questionnaire the manufacturers received another prepared by the American Society for Testing Materials on the present methods employed in manufacturing steel shafting and the minimum values for elastic limit and tensile strength for the different sizes and kind of shafting produced by them. The real purpose of this inquiry was to secure data by which a minimum value of the unit stress for this material might be determined for the use of Professor Beyer's Sub-Committee. The response to these questionnaires has been very gratifying.

Standardization of Plain Limit Gages for General Engineering Work. A letter ballot on the first report to be completed by this Sectional Committee is now being taken. The report covers standard allowances and tolerances for fits in interchangeable manufacture, and is the part of the work assigned to the Sub-Committee of which George T. Trundle is chairman.

The Sub-Committee on Methods of Gaging Manufactured Material, headed by F. O. Hoagland, and the Sub-Committee on Gages and Their Limits, Manufacture and Use, presided over by Earle Buckingham, are both hard at work on their respective sections and promise reports in the near future.

Standardization of Pipe Flanges and Fittings. The all-day session which this Sectional Committee held in December produced many valuable suggestions which have been made good use of in preparing the revised drafts of the four flange standards which are now before the members of the Sectional Committee for approval. These standards are:

1 Cast-Iron Flange and Fittings Standards for 125 lb. Maximum (Saturated) Steam Working Pressure
2 Cast-Iron Flange and Fittings Standards for 250 lb. Maximum (Saturated) Steam Working Pressure
3 Cast-Steel Flange and Fittings Standards for 400 lb. Maximum Steam Working Pressure
   800 lb. Cold-Water Working Pressure—Hydrostatic (No Shock)
   500 lb. Cold-Water Working Pressure—Shock
   800 lb. Air or Gas Working Pressure—Temp. Not Exceeding 100 Deg. Fahr.
4 Cast-Steel Flange and Fittings Standards for 600 lb. Maximum Steam Working Pressure
   1200 lb. Cold-Water Working Pressure—Hydrostatic (No Shock)
   800 lb. Cold-Water Working Pressure—Shock
   1200 lb. Air or Gas Working Pressure—Temp. Not Exceeding 100 Deg. Fahr.

The Sub-Committee on Screwed Fittings is now at work on standard dimensions for cast-steel fittings and is preparing a supplementary report on the Malleable Fittings which will assign tolerances to certain of the dimensions.

Standardization of Bolt, Nut, and Rivet Proportions. At its December meeting this Committee elected as chairman, Arthur A. Norton, assistant professor of mechanical engineering, Harvard.

University. It also created an eighth Sub-Committee on Nomenclature which consists of the chairmen of the other seven Sub-Committees, the chairman and secretary of the Sectional Committee and is headed by George S. Case as chairman.

Tentative reports of four of the Sub-Committees are now being considered by the members of the entire Sectional Committee and are available for distribution to those who may desire to look them over. These reports cover:

1 Standards for Large and Small Rivets
2 Standards for Wrench-Head Bolts and Nuts
3 Standards for Slotted-Head Products
4 Standards for Carriage Bolts.

The Sub-Committee on Track Bolts, of which C. W. Squier is now chairman, held a meeting on March 9 and made a very careful survey of the large task assigned to it. A mass of data was laid before the Sub-Committee and this is being carefully studied as the first part of its program.

Safety Code for Mechanical Power-Transmission Apparatus. On February 8 this Sectional Committee held a meeting in New York at which were considered comments which had resulted from the circularization of galley proofs of this safety Code. The correspondence and the discussion at the meeting centered very largely around Rule No. 313 which covers the use of metal belt lacing on belts shifted by hand. A number of representatives of the manufacturers of this material were present and after considerable discussion this rule was revised to read as follows:

Rule 313—Belt Fasteners

Belts which of necessity must be shifted by hand and belts within six (6) feet of the floor or working platform which are not guarded in accordance with the intent of this code shall not be fastened with metal in any case nor with any other fastening which by construction or wear will constitute an accident hazard.

The final revision of the text of this Code are now finished and it is before the Sectional Committee for vote. Copies, therefore, will soon be ready for distribution.

Safety Code for Elevators. Sullivan W. Jones, a representative of the A.I.A. on the Sectional Committee and now New York State Architect, was elected chairman of this Committee at the meeting it held on February 19, 1923. At this meeting an Executive Committee was appointed consisting of S. W. Jones, Chairman, O. P. Cummings, Vice-Chairman, J. A. Dickinson, Secretary, M. B. McLauthlin, C. H. Weeks, and K. A. Colahan.

After the Committee had increased its personnel by electing Byron Cummings and D. L. Lindquist as members at large, it turned its attention to the report of its Plan and Scope Committee, of which Bassett Jones was chairman. As the result of the discussion which followed the presentation of this report, the chairman was directed to appoint two Sub-Committees and to develop with the assistance of the Executive Committee a strong Advisory Committee. The first of these Sub-Committees is to be charged with the interpretation and revision of the Code. It will maintain contact with the various regulatory and other interested bodies for the purpose of answering specific questions about the Code, to issue special interpretations and to recommend such changes to Sub-Committee No. 2 which have been suggested by these regulatory bodies or others.

The task assigned to Sub-Committee No. 2 is fourfold; (*a*) to indicate the sections of the present A.S.M.E. Code which apply to existing installations; (*b*) to revise the present Code wherever necessary to cover completely new installations; (*c*) to draft a set of rules for operation and inspection; and (*d*) to compare existing rules of various states and cities so that the Sectional Committee shall at all times be thoroughly informed.

The Federated American Engineering Societies

Labor-Saving Machinery

At a meeting of the Committee on Procedure of the American Engineering Council, held on February 16, 1923, the advisability of making an intensive study of labor-saving devices was brought up for consideration. Walter S. Moody, of the General Electric Company, Pittsfield, Mass., who, in a communication addressed to President Cooley, first suggested such an investigation as a means of overcoming the present labor shortage in the United States, stated that in his opinion a large amount of labor now performed by hand could be accomplished by power-driven devices, thereby releasing great numbers of men for other and higher-grade work. He advocated a general survey of industry for the purpose of selecting kinds of work now done manually where machinery might be employed, followed by the coöperation of industries and suitable engineering organizations in the development of the necessary devices.

The Committee believed the matter to be of very great importance and after discussion voted that it be referred to The American Society of Mechanical Engineers to ascertain, first, if the A.S.M.E. considers such an investigation opportune and practical; and second, if that society will undertake the study or, in case it does not desire to do so, if it advises that the work be undertaken by American Engineering Council, and in what form.

Reforestation

Reforestation, involving such agricultural and industrial problems as soil conservation, flood control, and power development, is one of the projects now being studied by a special F.A.E.S. committee, in coöperation with the Government. The chairman of this committee, which was appointed to assist in developing a comprehensive constructive plan of reforestation, is Charles H. McDowell of Chicago; other members are S. H. McCrory, chief of the Division of Agricultural Engineering, U. S. Department of Agriculture. W. H. Hoyt, of Duluth, Minn., and J. C. Ralston, of Spokane, Wash.

Chief McCrory, in an announcement of the project issued recently through Dean M. E. Cooley, president of the Federation, stated that in the past land development and utilization has depended largely upon local initiative but that consideration must soon be given to the probable needs of the United States for crop, pasture, and forest lands. America's supply of timber, which has been decades in growing, is rapidly being exhausted. If timber is to be grown to replenish the supply, a considerable acreage must be permanently devoted to this purpose. He pointed out that the easily developed tillable land has nearly all been brought into use, and emphasized the need for the most effective utilization of undeveloped lands, clearing, draining or irrigating for crop and pasture land, or reserving for timber growth.

The committee believes it essential that mountainous regions such as the Appalachian area be kept timbered in order to minimize erosion. The watersheds of rivers must not be divested of timber, otherwise erosion will be rapid and power development retarded. The committee is supporting legislation for the establishment of a national hydraulic laboratory to study flood control.

Eyesight Conservation Council

A continuation of one phase of the work of the Committee on the Elimination of Waste in Industry is being conducted by the Eye Sight Conservation Council of America, which is directing a campaign to eliminate economic and physical losses due to poor eyesight in schools and factories, and to conserve vision. The Waste Report showed that poor eyesight among workers causes heavy annual economic losses. A similar condition exists in schools.

L. W. Wallace, executive secretary of the F.A.E.S. was reëlected president of the Eye Sight Conservation Council at its annual meeting, held in New York, February 5, and Guy A. Henry, of New York, was reëlected general director. Others recently appointed to the governing bodies of the Council are Secretary Davis, of the U. S. Department of Labor, and Prof. F. C. Caldwell of the Department of Electrical Engineering, Ohio State University. Among those serving on the Board of Directors and the Board of

Councilors are Prof. J. W. Roe, New York University, president of the Society of Industrial Engineers; Dr. Morton G. Lloyd, chief of the Safety Section of the U. S. Bureau of Standards and vice-president of the American Society of Safety Engineers; and G. E. Sanford, of West Lynn, Mass., past-president of the American Society of Safety Engineers.

The personnel of those assisting in the movement includes also representatives of the U. S. Department of Education, the U. S. Public Health Service, and numerous other engineering and educational bodies.

Passage of Bill for Reclassification of Governmental Positions and Salaries

ONE OF THE closing acts of the sixty-seventh Congress was the passage of the Sterling-Lehlbach Bill for the Reclassification of Governmental Positions and Salaries, H. R. 8928. As a means of maintaining a high standard of scientific and technical service of the Government, this bill has received the active support of the F.A.E.S. through its committees on patents and on reclassification and compensation of engineers. A delegation of engineers headed by Col. J. H. Finney, a member of the Patents Committee, was instrumental in securing its passage before Congress adjourned.

Although the law will not go into effect until July 1, 1924, it undoubtedly has an immediate benefit. High-grade professional men already in Government employ, with the definite salary increase before them, will feel that they can "stay by the ship," and others of similar type will be drawn into Government service, filling many vacancies which low salaries have caused. Until the law goes into effect the present basic rates of pay, plus the $240 bonus that has been paid for the last six years, will continue.

The bill as finally passed by the House carries revisions made by the Senate. In the Patent Office, for instance, primary examiners will receive $5040 instead of $4600. The enactment of the Lambert Patent Office Bill, early in 1922, prevented the complete collapse of the Patent Office; the salaries under the Sterling-Lehlbach law will attract for new appointments a high grade of men. In the course of time the whole examining corps will be raised in quality. The law will equally benefit all other professional and scientific branches of the Government.

Engineering organizations have done much to secure the passage of these two important bills. Engineers may be justly proud of their part in completing the task set before them. Such success should make them realize that they do have a strong national influence and should go a long way toward bringing about whatever seems to them just and wise.

Reorganization of Government Departments

THE OUTLINE of the plan for the reorganization of the executive departments of the U. S. Government as recommended by the President and the Cabinet at the request of the Joint Committee on Reorganization was recently placed in the hands of that committee for consideration. The outstanding recommendations are as follows:

I The coördination of the Military and Naval Establishments under a single Cabinet officer, as the Department of National Defense.

II The transfer of all non-military functions from the War and Navy Departments to civilian departments—chiefly Interior and Commerce.

III The elimination of all nonfiscal functions from the Treasury Department.

IV The establishment of one new department—the Department of Education and Welfare.

V The change of the name of the Post Office Department to Department of Communications.

VI The attachment to the several departments of all independent establishments except those which perform quasi-judicial functions or act as service agencies for all departments.

The suggested changes of particular interest to engineers are found in the Department of the Interior and Commerce. The Interior Department is given two major functions: the administration of the public domain and the construction and maintenance of public works. The subdivisions of the department are grouped accordingly under two assistant secretaries. The Bureau of Mines and the Patent Office are transferred to the Department of Commerce, and the non-military engineering activities of the War Department, the Supervising Architect's Office of the Treasury Department, the Bureau of Public Roads of the Department of Agriculture, and the Federal Power Commission, an independent establishment, are all transferred to the Department of the Interior.

The three major functions given to the Department of Commerce are the promotion of industry, the promotion of trade, and the development, regulation, and protection of the merchant marine, each division under an assistant secretary. In addition to the transfer of the Bureau of Mines and the Patent Office from the Department of the Interior, the Department of Commerce is given the Lake Survey, the Inland and Coastwise Waterways Service, the supervision of New York Harbor, the Hydrographic Office and the Naval Observatory, and the Life Saving Service.

While this plan does not provide for the establishment of a National Department of Public Works, which has been advocated by engineering organizations, the proposed transfers have in view the same object, that of bringing together related activities. The outline has been studied in detail by the Federation's Committee on Government Reorganization as it Relates to Engineering Matters, of which J. Parke Channing, New York, is chairman, and was reported upon to the Executive Board, at its meeting in Cincinnati, March 23–24, 1923.

Discussion on Effect of Pulsations on Flow of Gases

(Continued from page 229)

perhaps nearly eliminated, by the use of the proper amount of throttling observing at the same time that equal spaces were provided at the manometer connections for varying quantities of flow. They concluded that it was an extremely doubtful and uncertain method, if not wholly dangerous, to rely too fully on such expedients for reducing the pulsating error.

The question raised in regard to the relative effect of the pulsation on the static pressure was answered, the authors believed, in the reply to Mr. Packard.

The authors agreed with Mr. Hodgson and Mr. Packard that the velocity of propagation of the pulsating wave approached that of sound in the flowing fluid plus the velocity of the flowing air. However, in their opinion, as based on their experiments they were not willing to concede that the pressure pulsation had a less effect than the velocity pulsation in meter installations where these pulsations acted on manometers with static connections at right angles and even with the inside of the pipe. From the "dead-end" flow experiments it would also seem evident that the pressure pulsation effect was many times greater than that due to the velocity pulsation.

The statement was made by Mr. Hodgson that the simplest way of reducing the pulsation by the use of a capacity combined with throttling was not mentioned by the authors. In conclusion they had stated that the "muffler" device, a combination of capacity, or volume, with throttling was probably "the most effective device for the mechanical elimination of pulsations." The capacity or "muffler" was always inserted between the disturbing element and the meter. It would not seem advisable in their opinion, to insert the throttling device in the line below the meter. It would seem better to eliminate the pulsations as far as possible before the meter was reached.

The authors regretted that Mr. Hodgson's paper containing his latest investigations involving the development of a formula for pulsating flow had not been available for examination and study until after their paper was written. Mr. Hodgson was to be congratulated in being able to reduce the results of his researches to a working formula which showed the factors involved in their proper relation. They were in full accord with his opinion that the only sure way to meter pulsating flow was to reduce the pulsations by means of suitable capacity and throttling, and they likewise believed that even the formula proposed, or any similar formula, while serving in a general way could not be too rigidly applied in practice. Each installation would present its own peculiar problem.

Meetings of Other Societies

American Institute of Mining and Metallurgical Engineers

The 127th meeting of the American Institute of Mining and Metallurgical Engineers was held in New York, February 19–22, 1923. So valuable was each of its sessions to the group of engineers interested in the particular problem with which it dealt, that no session can be called outstanding.

The opening technical session on Monday morning was on the subject of ground movement and subsidence, which has received comparatively little treatment during recent years. Much interest was evidenced in the papers presented and the session was continued in the afternoon.

A meeting for the organization of a Division on Petroleum and Gas was held on the morning of the first day of the convention and three entire sessions were devoted to symposiums on this subject. Twenty-three papers covered oil developments throughout the world during 1922, and six papers dealt with miscellaneous oil-development problems.

Based upon replies to questionnaires sent out to a large number of mining companies during 1922, a number of papers on mining methods were presented at four mining sessions, one of which was devoted entirely to coal.

Two iron and steel sessions were held. At the first the A.S.T.M. Tentative Specifications for Foundry Pig Iron were presented and the discussion led by Dr. Richard Moldenke, Watchung, N. J. Dr. Moldenke is chairman of the A.S.T.M. Committee on Cast Iron, at whose request the specifications were presented at the Institute meeting. The specifications were thought to be liberal in character and were favorably received.

At the same session Norman B. Pilling, Research Department, Westinghouse Elec. & Mfg. Co., gave an illustrated talk on Low-Temperature Brittleness in Silicon Steels. He stated that temporary ductility may be obtained by carrying on cutting or deformational operations at temperatures slightly above atmospheric, the temperature depending on the steel composition, and that brittleness is only slightly modified by heat treatment.

Speaking at the second session on iron and steel, W. R. Bean, Naugatuck, Conn., stated that the deterioration of malleable in the hot-dip galvanizing process is intimately connected with the phosphorus and silicon contents of the iron. In general, low-phosphorus (under 0.15 per cent), low-silicon (under 0.80 per cent) iron will withstand the process best and show practically no deterioration. High-phosphorus, high-silicon irons are practically certain to deteriorate and be embrittled by galvanizing. A second paper at this session, dealing with the influence of temperature, time, and rate of cooling on physical properties of carbon steel, gave the results of an investigation of the heat treatment of carbon steels carried out under the auspices of the Committee on this subject of the Engineering Division of the National Research Council.

There was also a joint session on iron and steel and coal and coke, at which blast-furnace cokes and coke ovens were considered.

Joint sessions were held with the Industrial Relations Committee and Mining Section of the National Safety Council, at which hoisting ropes and mine-fire prevention were the main subjects considered. An interesting paper on Non-Destructive Testing of Steel Hoisting Rope by Raymond L. Sanford, physicist of the National Bureau of Standards, was presented and discussed. It outlined work soon to be undertaken by that bureau to develop if possible suitable magnetic methods of testing steel hoisting ropes.

Technical education was discussed at a joint meeting with the Mining and Metallurgical Society of America. One of the papers was by E. P. Mathewson, consulting metallurgist of New York and incoming president of the Institute, who gave his opinions on training engineering students, based upon his contact during thirty-five years with graduates of engineering schools all over the world.

Mechanical engineers will be chiefly interested in the papers presented under the auspices of the Institute of Metals Division. Dr. Walter Rosenhain, head of the metallurgical department of the National Physical Laboratory at Teddington, England, delivered the second annual Institute of Metals lecture, on the subject of Solid Solutions, to a large audience on February 19. The high quality of Dr. Rosenhain's lectures has been appreciated by many in this country who have heard him during recent months at various technical and educational institutions. It was announced that Dr. Zay Jeffries will deliver the lecture next year.

The Nature of Solid Solutions was the title of a paper by Edgar C. Bain, of the General Electric Company, Cleveland, Ohio. E. H. Dix, Jr., described methods of polishing aluminum and its alloys for metallographic study as employed in the metallurgical laboratory of the Engineering Division of the U. S. Air Service, McCook Field, where he is chief of the Metals Branch. Junius D. Edwards, assistant director of research, Aluminum Company of America, spoke on the thermal properties of aluminum-silicon alloys, dealing with the accurate determination of densities of aluminum alloys containing variable amounts of silicon and presenting data on crystallization shrinkage, total solid shrinkage, and the tendency to form pipe.

Christopher H. Bierbaum, vice-president of the Lumen Bearing Company, Buffalo, N. Y., in an address on bearing metals, described an instrument developed for use in determining the relative hardness of individual crystals in the bearing metal and the journal.

Among the other papers was one on tests on high-tin bearing metals, including remarks on the chemical composition and microstructure of suitable alloys, directions for casting in bronze shells, and data on tests of commercial alloys for hardness, compressive strength, and coefficient of friction; a paper on the thermal conductivity of some industrial alloys; and one on the bright annealing of copper wire.

At the annual dinner of the Institute, at which Prince Gelasio Gaetani, the Italian ambassador, was guest of honor, the James Douglas medal was awarded to Frederick Laist, manager of the reduction plant of the Anaconda Copper Mining Co., Butte, Mont., for achievements in non-ferrous metallurgy.

E. P. Mathewson was elected president of the Institute to succeed Col. Arthur S. Dwight.

American Institute of Electrical Engineers

Out of the unusually large number of technical papers presented at the Eleventh Midwinter Convention of the American Institute of Electrical Engineers, held in New York, February 14–17, 1923, are several which are of interest to mechanical engineers. E. J. Blake, electrical engineer for Gould Coupler Co., Depew, N. Y., reviewed the circumstances which have made train control an acknowledged problem and stated the characteristics desired in automatic train-control devices. Automatic control, he believed, should act as a check on manual control, not as a substitute. It should conform to established safe signaling practices, should be designed for the severe conditions of railway operation, should not conflict with existing signals or otherwise introduce new hazards, should so far as possible conform to existing clearance lines and should not impede traffic. Methods of transmitting and indication of track conditions to the train which he described were (1) by intermittent mechanical and electric contact; (2) by intermittent induction through the use of permanent or electromagnets; and (3) by continuous induction from the rails. Relations between the type of controlling action and traffic capacity were also discussed by Mr. Blake.

Applications and Limitations of Thermocouples for Measuring Temperatures was the subject of an address by Irving B. Smith, Research Department, Leeds & Northrup Co., Philadelphia, Pa. He classified temperature measurements under the heads of feed-water, boiler water, economizer, flue gas, superheated steam, bearings, generator windings, transformer windings, and cables. The sources of error that may arise in making temperature measurements with the thermocouple were outlined as residing in thermocouple calibration, instrument calibration, thermocouple circuit, radiation losses, conduction losses, parasitic e.m.f., temperature lag, cold-junction temperature, measured temperature variable, and measured temperature not representative. Mr. Smith considered these classifications and sources of error in detail.

At the same session J. W. Legg, consulting engineer for Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa., presented a paper

on the Expansion of Oscillography by Portable Instrument, describing fully the oscillograph in its redesigned form and discussing its possibilities. The new instrument has been constructed along the same general principles as the early portable oscillograph, but has been reduced in bulk about fifty per cent and considerably improved. It is complete in one unit and is designed to operate from any standard 6-volt storage battery.

A feature of the meeting which aroused great interest was the joint session with Chicago on the evening of February 14, made possible by two-way loud-speaking telephone installations. The proceedings of the meeting were also broadcast. Speakers on the use of public-address systems with telephone lines discussed the various applications of this novel combination, stated requirements for the lines, showed the circuit arrangements used, and described some of the important operating features. The application of the public-address-system apparatus and methods to radio broadcasting were also briefly discussed.

Inspection trips to the McGraw-Hill Company, the Pennsylvania Exchange of the New York Telephone Company, the Bell System Research Laboratories, and the A.T. & T. Broadcasting Station were made during the convention.

American Society of Heating and Ventilating Engineers

Following a business session in New York on January 23, the American Society of Heating and Ventilating Engineers held the first technical session of its twenty-ninth annual meeting at the Bureau of Standards in Washington, January 24. The morning was devoted to Bureau of Standards papers on subjects of great importance to heating and ventilating engineers, which were based on current research in the laboratories of the Bureau; the afternoon was given over to an inspection of the laboratories and an explanation of the methods of investigation. The papers presented were Heat Transmission of Building Structures, by M. S. Van Dusen; The Testing of Anemometers, by O. J. Hodge; and Tests of Radiator Return Line Valves, by W. F. Stutz. S. H. Ingberg gave a talk on Fire Tests of Structural Materials.

On January 25 a research session was held at the Bureau of Standards at which F. Paul Anderson spoke on The Research Laboratory, and papers on the physiological reactions of humans to high temperatures and high humidities, equal-comfort lines for still-air conditions, the capacities of steam-heating risers as affected by critical velocities of steam and condensate mixtures, and the Anderson and Armspach dust determinator were presented. The latter paper included information on results obtained in a series of tests upon the dust determinator, as well as a description of the apparatus.

The other sessions of the meeting were held at the Hotel Washington on January 24 and 26. At the first, M. S. Cooley of the Bureau of Yards and Docks, told how the new gun shop at the U. S. Navy Yard is heated, describing in detail the hot-blast system which is provided with fans and heaters in roof spaces and distributing ducts alongside of columns. C. R. Denmark, engineer at the Smithsonian Institution, gave details of the forced hot-water circulation and air-exhaust systems in the Natural History Building, of the U. S. National Museum. Nelson S. Thompson, chief mechanical and electrical engineer, Office of Supervising Architect, U. S. Treasury Department, pointed out the simplicity of the heating and ventilating systems installed at the Bureau of Engraving and Printing.

Heating and ventilating sessions were held on the closing day of the convention, at which a number of interesting papers and reports were heard. F. B. Rowley, professor of mechanical engineering at the University of Minnesota, gave a report of tests of five distinct types of roof ventilators and described the method and apparatus used in making the tests. Dr. George T. Palmer, of the Michigan Department of Health, outlined ventilation practice since 1850 and indicated what developments may be expected in the near future. H. L. Dryden discussed wind-tunnel tests of roof ventilators.

The program included various sight-seeing and inspection trips to the many beautiful institutions which are to be found both in and around Washington.

LIBRARY NOTES AND BOOK REVIEWS

Analytic Geometry. By Clyde E. Love. Macmillan Co., New York, 1923. Cloth, 5 × 8 in., 306 pp., $2.25.

A textbook for beginners, covering the elements of plane and solid analytic geometry. The emphasis is placed on geometry rather than on analysis to a greater extent than usual, and the course is intended to give the student, first, a knowledge of simple fundamental methods, and then to extend, adapt, and generalize these as need arises.

Comparison of British and American Foundry Practice. By P. G. H. Boswell. University Press of Liverpool, Liverpool; Hodder & Stoughton, London, 1922. Paper, 6 × 9 in., 106 pp., illus., diagrams, tables, 4s. 6d.

The author of this work was sent to the United States in 1918 by the British Ministry of Munitions of War, to investigate American foundry practice, particularly as regards the use of sands for steel molding. For this purpose he visited the principal iron, steel, and brass foundries, the quarries and other sources of refractories, and research laboratories. His report discusses the casting of metals, desiderata in molding sands, the molding-sands used in America, bonding of molding sands and silica sands for furnace hearths. British and American methods are compared. Tables give chemical and mechanical analyses and the mineralogical composition of a number of American and European sands.

Construction and Exploitation des Grandes Réseaux de Transport D'Energie Électrique a Trés Haute Tension. Proceedings of the International Conference held in Paris November 21–26, 1921. L'Union des Syndicate de L'Electricite, Paris, 1922. Cloth, 7 × 10 in., 1176 pp., illus., diagrams, 100 fr.

The reports of this conference are now available in a well-printed volume of nearly twelve hundred pages containing a review of its organization and purpose, a general report of its activities, and the text of the sixty-eight reports presented before it. These reports include summaries of the legislation pertaining to high-tension transmission in various countries, descriptions of existing systems and projects, papers upon various topics connected with current production and transformation, the construction of high-tension lines, and the exploitation, protection, and safeguarding of transmission systems. The conference was attended by delegates from twelve countries. The papers and discussions give a wide survey of the present status of high-tension transmission.

Descriptive Geometry. By Lawrence E. Cutter. First edition. McGraw-Hill Book Co., London and New York, 1923. Cloth, 6 × 9 in., 244 pp., diagrams, $2.50.

In descriptive geometry there are two general methods of applying its fundamental principles: one, the method of rotation; the other, the method of choosing new projection planes. The present book is the first, the author states, prepared on the latter plan, which he considers superior in utility to the first plan, and equally good in point of mental discipline.

In it theory has been reduced to four simple principles, covering one page of the text. The use of these is illustrated through the detailed solution of problems from the fields of civil, mechanical, and mining engineering, and of architecture. Original exercises for solution are given.

Diesel Engine. By A. Orton. Isaac Pitman & Sons, London and New York, 1923. (Pitman's Technical Primers.) Cloth, 4 × 6 in., 111 pp., diagrams, tables, $0.85.

The aim of this book is to act as an introduction for those intending to study the subject thoroughly, and also to serve as a broad but fairly complete treatment for those who seek just sufficient

knowledge to understand and apprehend the principles of working, construction, and operation. The author has endeavored to treat the subject in the simplest possible manner, without omitting anything of vital importance. A bibliography, confined to British publications, is included.

Optical Methods in Control and Research Laboratories. By J. N. Goldsmith and others. Vol. 1, Second edition. Adam Hilger, London, 1923. Limp cloth, 6 × 10 in., 56 pp. illus., 1s 6d.

The optical methods here dealt with are those employing spectroscopes, spectrophotometers, refractometers and polarimeters. The book is intended to provide the works chemist with a guide to the selection of these instruments, an introduction to their use in metallurgy and analytical chemistry and an index to sources of further information concerning their use in research and control laboratories. The book is confined to these indications of the usefulness of these instruments, and does not include detailed descriptions of their design or their techniques; for information on these points, references are given to other publications.

Principles and Practice of Toothed Gear Wheel Cutting. By George W. Burley. Scott, Greenwood & Son, London; D. Van Nostrand Co., New York, 1922. Cloth, 6 × 9 in., 460 pp., illus., diagrams, tables, $8.

This book deals with the fundamental principles of all the several descriptions of toothed-wheel gearing now in use; the measurement of toothed-wheel gears, generating and non-generating methods for forming gear-wheel teeth mechanically, and the machines and tools that apply these methods. An attempt is made to treat both the theoretical and practical side of the subject.

The book is intended for students of engineering, apprentices, and machinists. The subject is not dealt with from the viewpoint of the designer.

Scientific Management. By Horace Bookwalter Drury. Third edition. Columbia University, New York, 1922. (Studies in history, economics and public law). Cloth, 6 × 9 in., 271 pp., $2.75.

Dr. Drury's account of the development of scientific management appeared originally in 1915. In 1918 a revised edition appeared which corrected the errors of the original edition and extended the account down to the latter date. The present edition is substantially a reprint of the 1918 edition, with a long introduction in which later tendencies and the present situation are described.

The volume is divided into two sections, historical and critical. The historical section gives an account of the genesis of scientific management, of the leaders in its development and of the trades and plants that adopted it. The critical section discusses its effect on productivity, on the labor problem and on the worker.

Steam Power. By C. F. Hirshfeld and T. C. Ulbricht. Second edition. John Wiley & Sons, New York; Chapman & Hall, London, 1922. Cloth, 5 × 8 in., 474 pp., illus., diagrams, $3.25.

In preparing this textbook the authors have attempted to collect in a comparatively small book such parts of the field of steam power as should be familiar to engineers whose work does not require that they be conversant with the more complicated thermodynamic principles considered in advanced treatises. They have therefore eliminated mathematical treatment as far as possible, and confined themselves to giving a correct viewpoint with regard to the use of heat in the power plant, to supplying what is required to solve common power-plant problems and to describing the more common types of apparatus.

Treatise on the Theory of Bessel Functions. By G. N. Watson. University Press, Cambridge, 1922. Cloth, 7 × 11 in., 804 pp., tables, $16.

The author states that this book has been designed with two objects in view. The first is the development of applications of the fundamental processes of the theory of functions of complex variables, for which purpose Bessel functions are admirably adapted. The second is the compilation of a collection of results which would be of value to the increasing number of mathematicians and physicists who encounter Bessel functions in the course of their researches. Such a collection seems to be demanded by the greater abstruseness of properties of Bessel functions which have been required in recent years in various problems of mathematical physics.

While the endeavor has been made to give an account of the theory of Bessel functions which a pure mathematician would regard as fairly complete, the author consequently has also endeavored to include all formulas which, although without theoretical interest, are likely to be required in practical applications. A very full bibliography is included.

Twelve-Hour Shift in Industry. By Federated American Engineering Societies. Committee on Work-Periods in Continuous Industry. E. P. Dutton & Co., New York, 1922. Cloth, 6 × 8 in., 302 pp., tables, $3.50.

The investigations reported upon in this volume were undertaken by the Federated American Engineering Societies in 1921. The objects were to ascertain the extent of two-shift work in continuous-process industries other than the manufacture of iron and steel, the experience of manufacturers who had changed from two-shift operation to some other system, and to study the technical aspects of changing from the two-shift to the three-shift system in the iron and steel industry.

This volume includes a report on the first two points prepared by Dr. Horace B. Drury and one on the third point by Mr. Bradley Stoughton, as well as a brief general summary of the conclusion to be drawn from their studies. These are favorable to the two-shift system.

Vector Calculus, with Applications to Physics. By James Byrnie Shaw. D. Van Nostrand Co., New York. Cloth, 5 × 8 in., 314 pp. $3.50.

Embodies the author's lectures to graduate students. The attempt has been to give a text to the mathematical student on the one hand, in which every physical term beyond mere elementary terms is carefully defined. On the other hand, for the physical student there is a large collection of examples and exercises which will show him the utility of the mathematical methods. The system adopted is algebraic.

New Revisions of A.S.M.E. Boiler Code, 1923

(Continued from page 263)

Part II

The following action was taken on this section:

Voted: That Part II, on Existing Installations, be placed in the Appendix as suggested rules for the old boilers.

Revisions on Locomotive Boiler Code

L-53 Revised:

L-53 All holes in braces, lugs and sheets for rivets or staybolts shall be drilled, or they may be punched, at least 1/8 in. less than full diameter for material not more than 5/16 in. thick, and at least 1/4 in. less than full diameter for material more than 5/16 in. thick.

Such holes shall not be punched in material more than 5/8 in. thick.

For finishing the rivet holes, the plates, butt straps, braces, heads and lugs shall be firmly bolted in position by tack bolts, for final drilling or reaming to full diameter.

The finished holes must be true, clean and concentric.

L-62 Revised:

L-62 Each safety valve shall be plainly marked by the manufacturer in such a way that the markings will not be obliterated in service. The markings may be stamped on the casing [body], cast on the casing [body], or stamped or cast on a plate or plates permanently secured to the casing (body), and shall contain the following:

a The name or identifying trademark of the manufacturer

b The nominal diameter

c The steam pressure at which it is set to blow

[*d* Blow down, or difference between the opening and closing pressures]

d [*e*] The weight of steam discharged in pounds per hour at a pressure 3 per cent higher than that for which the valve is set to blow

e [*f*] A.S.M.E. Std.

THE ENGINEERING INDEX

(Registered United States, Great Britain and Canada)

Exigencies of publication make it necessary to put the main body of The Engineering Index (p. 111-EI of the advertising section) into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.

AIRPLANES

Bristol. The Bristol 3-Seater Airplane. Aerial Age, vol. 16, no. 3, Mar. 1923, pp. 140–141, 2 figs. Taxiplane designed to compete economically with road transport. See also Aviation, vol. 14, no. 10, Mar. 5, 1923, p. 273, 2 figs.

Sailplanes. The Development of the Hannover Sailplane, Georg H. Madelung. Soc. Automotive Engrs.—Jl., vol. 12, no. 1, Jan. 1923, pp. 77–85, 15 figs. Difference between airplane-racer and sailplane problems; features of early gliders; analysis of rate of descent; section and best-chord determination; why it was not advisable to build biplane; form and arrangement of body; model test; constructional details; torque; static tests and safety factor.

ALLOY STEELS

Heat Treatment. The Heat Treatment of Alloy Steels, R. R. Moore and E. V. Schaal. Forging & Heat Treating, vol. 9, no. 2, Feb. 1923, pp. 113–121, 40 figs. Effect of heat treatment upon metallographic and physical characteristics of chrome-nickel, chrome-vanadium and chrome-molybdenum steels; results obtained at various drawing temperatures.

AVIATION

Experimental Work, Bureau of Standards. Aviation Work of the Bureau of Standards, Fay C. Brown. Aerial Age, vol. 16, no. 3, Mar. 1923, pp. 115–119, 5 figs. Work is for most part in coöperation with Army & Navy Air Service and Nat. Advisory Committee for Aeronautics; deals with aircraft structure and instruments, power plants and radiators; the aeronautical safety code.

BEARINGS, ROLLER

Spherical. Advantages of the Spherical Type Roller Bearing, H. E. Brunner. Ry. Age, vol. 74, no. 9, Mar. 3, 1923, pp. 517–519, 3 figs. New design which combines self-alignment, low frictional resistance and high capacity.

BOILER FEEDWATER

De-Aeration, Closed-Feed. A New Closed Feed System. Engineer, vol. 135, no. 3502, Feb. 9, 1923, pp. 155–156, 5 figs. System developed by Hick, Hargreaves & Co., consists of feed piping and auxiliaries which are arranged so that only de-aerated water is supplied to economizers and boilers.

BOILER FURNACES

Design for Drying Fuel. Furnace Design for Effective Drying, Zuce Kogan. Power Plant Eng., vol. 27, no. 5, Mar. 1, 1923, pp. 265–268, 8 figs. Special arrangements of grates and arches are essential for drying fuel with high-moisture content in boiler furnace.

BOILERS

Atmos. Superpressure. Swedish Boiler Operates at Pressure of 1500 Pounds, Edvin Lundgren. Power, vol. 57, no. 7, Feb. 13, 1923, pp. 238–241, 5 figs. Among features of Atmos. boiler, designed by J. V. Blomquist, are steam generation from centrifugally formed shells of water in rotating tubes of 12 in. diam. and evaporation of 60 lb. of water per hr. per sq. ft. of steam-making surface.

DIE CASTINGS

Metals for. Metals Used for Die-castings, A. G. Carman. Machy. (N. Y.), vol. 29, no. 7, Mar. 1923, pp. 516–518, 1 fig. Babbitts, zinc-base metals and aluminum alloys for die castings; specifications giving limits of weight and accuracy for die castings made from different metals.

DIES

Built-up. Advantages of Built-up Die Construction, C. E. Stevens. Machy. (N. Y.), vol. 29, no. 7, Mar. 1923, pp. 528–530, 5 figs. Points to be considered in designing dies, which have been incorporated in set of dies for producing rheostat base herein described.

EVAPORATION

Compression, Method of. Evaporation by Compression, Wilhelm Gensecke. Chem. & Met. Eng., vol. 28, no. 10, Mar. 7, 1923, pp. 448–456, 15 figs. Process now in operation in several important industrial plants in Europe, where it has proved a valuable factor in heat economy; also close study of heat consumption usually calculated in sugar industry.

FLOW OF FLUIDS

Thin Slits. Leakage Through Thin Clearance Spaces, Edgar Buckingham. Engineering, vol. 115, no. 2982, Feb. 23, 1923, pp. 225–227, 1 fig. Results of experiments on slits of rectangular section by Frank F. Fergusson; notes on stream-line flow; change to turbulent flow; comparison of rectangular with annular slits; equations for computing resistance of thin, smooth, annular channels. Published by permission of U. S. Bur. of Standards.

FORGING

Flow of Metal During. The Flow of Metal During Forging, Harold F. Massey. Forging & Heat Treating, vol. 9, nos. 1 and 2, Jan. and Feb. 1923, pp. 25–30 and 122–127, 33 figs. Discussion of flow of metal when forged in hot state; special emphasis given to relation existing between action of forging by press and hammer. Paper read before Manchester Assn. Engrs.

GRINDING

Centerless. The Production of Small Parts by Centerless Grinding, Howard Campbell. Am. Mach., vol. 58, no. 10, Mar. 8, 1923, pp. 357–359, 10 figs. Examples of centerless grinding, together with figures on production; methods of handling odd work; grinding tungsten bars.

INDUSTRIAL MANAGEMENT

Engineering Department. The Successful Operation of an Engineering Department, W. E. Irish. Indus. Management (N. Y.), vol. 65, no. 3, Mar. 1923, pp. 136–141. Discussion of actual operation of department organized on principle described in previous articles.

Production Planning. How Production Planning Cuts Costs, H. S. Owen. Indus. Management (N. Y.), vol. 65, no. 3, Mar. 1923, pp. 182–187, 13 figs. Describes system of planning which, in actual operation, has produced very profitable results.

INTERNAL-COMBUSTION ENGINES

Explosion Tests. Internal Combustion Heat Losses and Specific Heat of Working Fluid, Wm. J. Walker. Engineer, vol. 135, no. 3504, Feb. 23, 1923, pp. 191–192, 1 fig. Discusses extent of transparency of combustion products of normal mixture to its own radiated heat; test determinations of values of specific heats at constant pressure and volume.

IRON CASTINGS

Annealing. Effect of Annealing Gray Iron, J. F. Harper and P. S. MacPherran. Foundry, vol. 51, no. 5, Mar. 1, 1923, pp. 176–180, 11 figs. Test bars heated at different temperatures for various lengths of time show changes in strength and hardness caused by annealing; results charted and micrographs shown. Paper before Am. Foundrymen's Assn.

Softening Gray Iron by Annealing, E. Piwowarsky. Forging & Heat Treating, vol. 9, no. 2, Feb. 1923, pp. 127–129, 1 fig. Object and theory of annealing of cast iron; experiments to soften by annealing; most certain method to accomplish this end. Translated from Stahl u. Eisen, Sept. 28, 1922.

LABORATORIES

Hydraulic Testing. A Well-Designed Hydraulic Testing Laboratory, John S. Carpenter. Power, vol. 57, no. 9, Feb. 27, 1923, pp. 331–332, 5 figs. Describes public testing flume built by Holyoke Water Power Co. at Holyoke, Mass.; laboratory equipment.

LOCOMOTIVES

Mikado. Most Powerful Mikados on the Lackawanna Railroad. Ry. Rev., vol 72, no. 7, Feb. 17, 1923, pp. 279–285, 10 figs. partly on supp. plate. Latest Mikado-type locomotives develop 79,200 lb. tractive effort. See also Ry. Age, vol. 74, no. 9, Mar. 3, 1923, pp. 510–513, 2 figs.

Pacific and Mikado. Locomotives for Brazilian Centennial Exhibition. Ry. Age, vol 74, no. 8, Feb. 24, 1923, pp. 467–468, 3 figs. Two Pacifics and a Mikado displayed by Am. Locomotive Co.

Superheater. Southern Railway—Three-Cylinder Simple Superheater Locomotive. Engineer, vol. 135, no. 3504, Feb. 23, 1923, pp. 200–201, 3 figs. 2-6-0-type engines, built at Ashford works to design of R. E. L. Maunsell. See also Ry. Gaz., vol. 38, no. 8, Feb. 23, 1923, pp. 282–283, 3 figs.

MEASURING INSTRUMENTS

Small Motions. Precision Measuring Instrument for Small Motions of Solid Bodies, H. A. Thomas. Engineer, vol. 135, no. 3502, Feb. 9, 1923, pp. 138–140, 12 figs. Apparatus consists essentially of high-frequency electrical oscillator in which amplitude of oscillation is varied by motion of body under observation.

MOTOR TRUCKS

American Specifications. American Trucks Approach Standard Design in Major Features. Automotive Industries, vol. 48, no. 8, Feb. 22, 1923, pp. 402–419, 6 figs. Specifications indicate only slight changes over last two years. Specifications for gasoline trucks and motor buses.

Axle, Triple Reduction. Triple Reduction Features New 5-Ton L M Truck Axle. Automotive Industries, vol. 48, no. 9, Mar. 1, 1923, pp. 518–519, 2 figs. Said to be more compact than one of double-reduction type with same ratio; differential placed on highest-speed shaft where stresses are lowest; first and third reductions by spur gears, second by bevels.

OIL ENGINES

Heavy Oil Engines, Evolution of. The Evolution of the Heavy Oil Engine, R. E. Mathot. Engineer, vol. 135, no. 3502, Feb. 9, 1923, pp. 137–138. Comparison of four-stroke explosion motors with Diesel engines operating on same cycle. Points out advantages of moderate pressures applied to engines without use of compressed air for fuel pulverization.

OPEN-HEARTH FURNACES

Krupp Plant. Krupps Build New Open Hearths. Iron Trade Rev., vol. 72, no. 9, Mar. 1, 1923, pp. 661–663, 4 figs. Plant started during war and recently remodeled one of most complete in Europe; cold-metal process used now, but provisions are made for molten-metal process in future.

PUMPS, CENTRIFUGAL

Extraction. A New Condenser Extraction Pump. Engineer, vol. 135, no. 3502, Feb. 9, 1923, p. 152, 2 figs. New type of high-vacuum centrifugal extraction pump placed on market by Mirrlees Watson Co., which will form one of integral units of Mirrlees closed-feed system; chief feature is elimination of all air leakage. See also Iron & Coal Trades Rev., vol. 106, no. 2867, Feb. 9, 1923, p. 185, 4 figs.

RAILWAY ELECTRIFICATION

Chicago, Milwaukee & St. Paul Ry. Railway Electrification, Arthur L. Mudge. Eng. Jl. (Eng. Inst. Can.), vol. 6, no. 3, Mar. 1923, pp. 127–133, 5 figs. Notes on electrification of Chicago, Milwaukee & St. Paul Ry. Comparison with steam operation; transmission lines and substations; locomotive inspection and maintenance.

German Report. The Electrification of the German Railways. Engineer, vol. 135, no. 3503, Feb. 16, 1923, p. 169. Excerpt of report of sub-committee appointed by Assn. German Ry. Administrations, containing information on question of system and proposed standards. Notes on Berlin, Austrian Federal and Dutch railways.

RAILWAY SIGNALING

Interlocking. Signaling Increases Capacity of Three Tracks. Ry. Age, vol. 74, no. 9, Mar. 3, 1923, pp. 498–501, 6 figs. Automatic signaling and interlocking plants on 21-mi. stretch of third track nearing completion on Ill. Central; center track signaled both ways, with interlocking, allows fast trains to pass slow ones.

RAILWAY TIES

Preservative Treatment. Creosote Shortage Threatens Wood Preservation, C. M. Taylor. Ry. Age, vol. 74, no. 9, Mar. 3, 1923, pp. 505–507, 3 figs. Mixing crude oil with creosote, it is claimed, will increase supply and provide necessary protection.

RAILWAYS

Engineering Problems. The Railroad Engineer and the Needs of Tomorrow, W. S. Kinnear. Eng. News-Rec., vol. 90, no. 10, Mar. 8, 1923, pp. 428–431. Survey of problems of railway development and plea for policy that will help engineer to solve them.

SCREW MACHINES

High-Speed Automatic. Screw Machine Products Made in Less than Three Seconds, Luther D. Burlingame. Machy. (N. Y.), vol. 29, no. 7, Mar. 1923, pp. 507–511, 9 figs. Examples showing how rapid production is obtained by careful tooling and machine timing. High-speed automatic screw machines of Brown & Sharpe Mfg. Co.

STANDARDIZATION

Germany. Standards in Germany Industry, George E. Hagemann. Management Eng., vol. 4, no. 3, Mar. 1923, pp. 183–188, 4 figs. Total number adopted to date is 870 and about 15 are added monthly. Organization of German Industrial Standards Committee; working up a standard; similarity to American method. Table of standards adopted up to January, 1923.

STEAM-ELECTRIC PLANTS

Ford Plant, River Rouge. Ford Principles and Practice at River Rouge, John H. Van Deventer. Indus. Management (N. Y.), vol. 65, no. 3, Mar. 1923, pp. 149–160, 28 figs. Development and operation of power plant.

STEEL

Tensile Tests. Tensile Tests of Materials at High Temperatures, F. C. Lea. Engineer, vol. 135, no. 3503, Feb. 16, 1923, pp. 182–183, 3 figs. Apparatus used; effect of temperature on fatigue range of stress static tests of nickel-chrome and high-carbon steels at high temperatures. (Abstract.) Paper read before Junior Instn. Engrs.

STRESSES

Repeated, Failure under. The Effect of Repetition Stresses on Materials, F. C. Lea. Engineering, vol. 115, nos. 2981 and 2982, Feb. 16 and 23, 1923, pp. 217–219 and 252–254, 15 figs. Experimental study; results of endurance tests; optical and thermal methods of determining fatigue ranges. Paper read before Instn. Civ. Engrs.

THERMOMETERS

Mercury. The Exposed Stem Correction for Mercury Thermometers, Wm. L. DeBaufre. Power, vol. 57, no. 9, Feb. 27, 1923, pp. 320–321, 4 figs. Measuring temperature of exposed stem; ordinary and direct formula for correction; method of constructing large-scale chart for direct formula.

Mechanical Engineering

The Monthly Journal Published by

The American Society of Mechanical Engineers

Publication Office, 207 Church Street, Easton, Pa. Editorial and Advertising Departments at the Headquarters of the Society, 29 West Thirty-ninth Street, New York

Volume 45 | May, 1923 | Number 5

CONTENTS OF THIS ISSUE

DEPARTMENTAL

ADVERTISING

Price 50 Cents a Copy, $4.00 a year: to Members and Affiliates, 40 cents a Copy, $3.00 a Year. Postage to Canada, 75 Cents Additional; to Foreign Countries, $1.50 Additional. Changes of address should be sent to the Society Headquarters.

Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879.
Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921.

Contributors and Contributions

The Cross-Flow Impulse Turbine

Forrest Nagler

The advancement of civilization has followed closely on the perfection of prime movers. The first prime mover was a water wheel of the impulse type. Forrest Nagler's paper in this issue describes a new type of water wheel for high heads which departs radically in principle from present practice. Mr. Nagler received his B.S. in mechanical engineering from the University of Michigan in 1906 and since his graduation has been with the Allis-Chalmers Manufacturing Co. In his work on axial-flow hydraulic-turbine runners he has developed a suction type of high-speed, low-head runner which holds several world records for capacity. Life Membership in the A.S.M.E. was awarded him in 1919 for his paper describing this work.

Lignite Char

O. P. Hood, chief mechanical engineer of the U. S. Bureau of Mines and in charge of the Bureau's fuel investigations, discusses the handicaps and possibilities of lignite char as fuel. Before assuming his present position in 1911 Mr. Hood spent twelve years in the engineering department at Kansas State Agricultural College, and from 1898 to 1911 he was professor of mechanical and electrical engineering at the Michigan College of Mines. He holds degrees from Rose Polytechnic Institute.

Aluminum Bronze as an Engineering Material

W. M. Corse, chairman of the Division of Research Extension of the National Research Council, was graduated from the Massachusetts Institute of Technology with the degree of B.S. in 1899. He went to work immediately as a chemist and has specialized in the manufacture of non-ferrous alloys, principally brass and bronze. He has worked for the Detroit White Lead Works, the Detroit Lubricator Co., Titanium Bronze Co., the Ohio Brass Co., and the Monel Metals Products Company. At present he is consulting engineer for the International Nickel Co. and the Buffalo Bronze Die Case Corporation.

High-Temperature and High-Pressure Steam Lines

A paper giving available data and formulas on radiation and friction losses in pipe lines is presented by B. N. Broido, consulting engineer with the Superheater Co. Mr. Broido was born in Russia and educated in Germany. His early work on superheaters was done in Germany with the Seiffert Co. and the Egestorf Machine Manufacturing Co. In 1914 he came to this country where he took post-graduate work in New York City. Before assuming his present position Mr. Broido did designing work for the Roessler & Hasslacher Chemical Co. and the Philadelphia and Reading Railway Co. He has filed over forty patent applications.

Refinery and Rolling Mill for Monel Metal

Economic problems involved in selecting a site for a mill for rolling monel metal and facts leading to their solution are given by W. L. Wotherspoon in a paper describing such a mill at Huntington, West Va. Mr. Wotherspoon is of English birth and received his training at large engineering works in England and South Africa, where he was a member of the consulting staff of the Central Mining and Investment Corporation of Johannesburg. In 1912 he came to New York where he has been executive engineer in charge of engineering and construction work for the International Nickel Co.

Management Engineering in Paper Industry

R. B. Wolf is president of The R. B. Wolf Co., of New York City, an organization specializing in the design, construction, and operation of pulp and paper mills. He was graduated from Delaware College in 1896 as an electrical engineer, but two months after his graduation he determined to enter the paper business. Beginning as a "workman" he has worked in practically every department of a paper mill. He resigned his position as manager of the Spanish River Pulp and Paper Mills during the war to become staff assistant to vice-president Piez of the Emergency Fleet Corporation.

The Oil Venturi Meter

The measurement of the flow of viscous fluids is discussed in this issue by E. S. Smith, Jr., of the California National Supply Co. of Los Angeles. Mr. Smith, who is a graduate of the University of California, class of 1919, has done special research work at the University, and for two years was an engineer testing venturi and orifice meters at the Standard Oil Company's refinery at Richmond.

Boiler-Furnace Design

Edwin B. Ricketts, assistant to the chief operating engineer of the New York Edison Co., contributes a paper on boiler-furnace design to this issue. Mr. Ricketts received the degree of B.S. from Millsaps College in Mississippi in 1901. He has been employed by various iron and steel works throughout the country, and previous to his last connection with the N. Y. Edison Company he designed and built a glass-manufacturing plant for the United States Glass Co. of Pittsburgh.

A.S.M.E. Spring Meeting

Montreal, May 28-31

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Complete particulars of the final program are given in the April 22 issue of the A.S.M.E. News.

MECHANICAL ENGINEERING

Volume 45 May, 1923 No. 5

The Cross-Flow Impulse Turbine

Particulars Regarding a New Type of Water Wheel Designed for Use with High Heads

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THE ORIGIN of the first prime mover is lost in antiquity, but we are able to state with practical certainty that it was an impulse-type water wheel; more specifically, that it was of the impact type, a current wheel with flat paddles, but an impulse wheel nevertheless. Written descriptions of these wheels date back nearly 2000 years, and current wheels, modified possibly to a slight extent in the direction of breast wheels, are probably several times that old.

It is with the history of this type of prime mover, its modification to date, its present state of development and possible improvement that this paper is to deal.

The term "impulse" is commonly used with those wheels in which water is applied to the rotating element in a free jet with all its energy in the form of velocity. It will be so used here although the term is somewhat of a misnomer as modern impulse wheels develop power as much by reaction as they do by impulse or impact. The term "impulse" or perhaps better, "impact" might have been accurately used to designate the original current wheels and some of the pioneer forms, such as the hurdy-gurdy wheel, where the water was received on flat surfaces and no attempt was made to utilize the reaction of the water leaving the wheel. The modern wheel, however, receives the water without shock, completely avoiding what might be termed impact, and turns it by a smooth path into a relative direction substantially contrary to that of the motion of the wheel. The essential distinction between the hydraulics of the so-called impulse wheel and the reaction type is found in the fact that in the former the entire energy of the water received by the wheel is in the form of velocity.

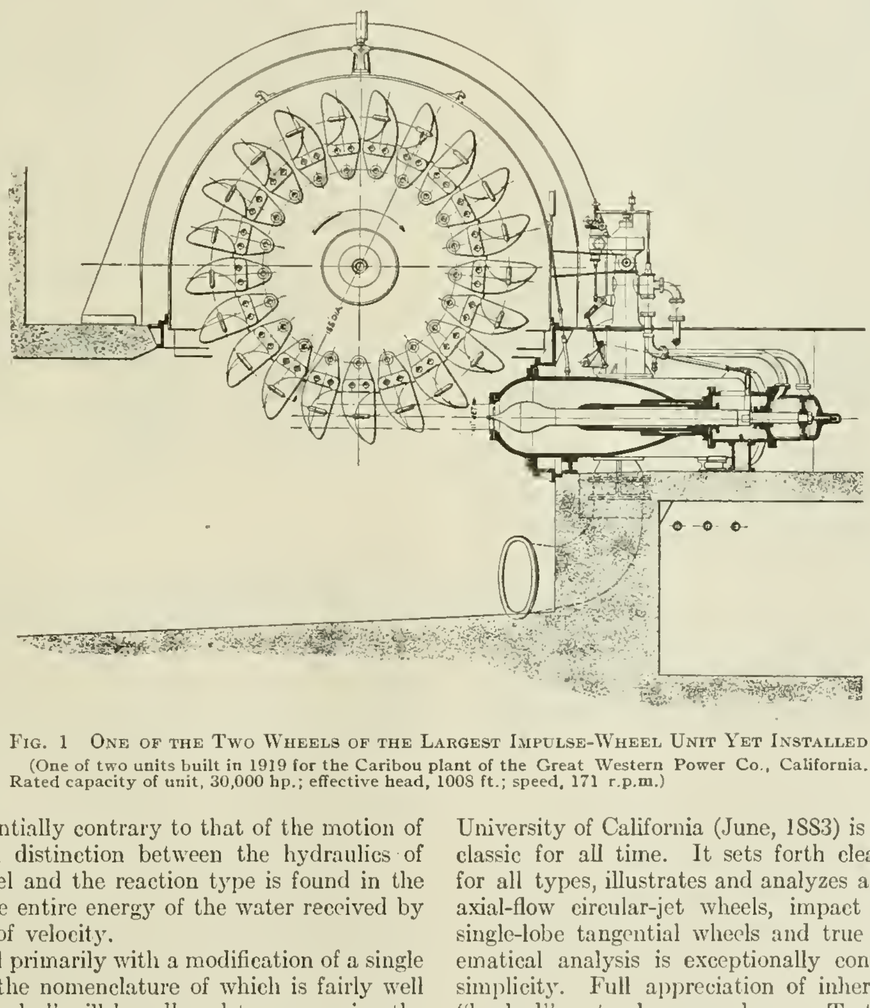

Fig. 1 One of the Two Wheels of the Largest Impulse-Wheel Unit Yet Installed
(One of two units built in 1919 for the Caribou plant of the Great Western Power Co., California. Rated capacity of unit, 30,000 hp.; effective head, 1008 ft.; speed, 171 r.p.m.)

As this paper has to deal primarily with a modification of a single type of wheel or turbine the nomenclature of which is fairly well established, the term "impulse" will be adhered to as covering the general and specialized forms known variously as Pelton, tangential, Girard, Schwankrug, pressureless, and impulse or action types as contrasted to Francis, Jonval, Fourneyron, pressure, and reaction. It is with this thought of conforming to accepted practice that the term "impulse" is employed.

Historical

Prior to recorded history we may infer that mankind required a matter of centuries to produce the flat-blade impulse wheel. We know that this type persisted with little or no change, up to about the sixteenth century A.D., that is, about two thousand years.

It required three hundred years more to definitely get beyond the flat-blade stage, realization of its disadvantages (only 50 per cent maximum theoretical efficiency) not materially affecting practice up to about 1850, although the faults of the flat blade were recognized 100 years previously. Some samples of the impact type of wheel survived in our own country up to the latter part of the nineteenth century, these being represented typically by the hurdy-gurdy wheel of the California mining days. Actual installations of this crude wooden wheel with its flat impact surfaces were made as late as 1880, but it gave way to the impulse wheel in approximately its present form, Fig. 6 (*a*), during the period of 1870 to 1880.

As late as 1883 and again in 1890–1891 comprehensive tests made on impulse wheels included tests on designs of flat-vane wheels. Bulletin No. 1 of the University of California (June, 1883) is probably the impulse-wheel classic for all time. It sets forth clearly the reaction principle for all types, illustrates and analyzes arrangements of radial- and axial-flow circular-jet wheels, impact wheels with flat surfaces, single-lobe tangential wheels and true splitter types. The mathematical analysis is exceptionally comprehensive without losing simplicity. Full appreciation of inherent disadvantages such as "backed" water loss was shown. Tests on impact wheels (40 per cent best efficiency) and Pelton wheels (82 per cent best efficiency) are given. Incidentally, this latter efficiency has not since been materially improved upon, considering the small jet size ($^3/_8$ in.) and low head (50 ft.).

Tests at the University of Michigan by Profs. M. E. Cooley, C. E. DePuy and L. J. Hill in 1890–91 similarly included tests on both impact and impulse wheels of commercial forms and with

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Presented at a meeting of the Milwaukee Section, Feb. 20, 1923. Also presented at the Pacific Coast Regional Meeting of The American Society of Mechanical Engineers, Los Angeles, Cal., April 16 to 18, 1923. Abridged.

modifications to improve the efficiencies of both. A maximum of 37 per cent with flat blades and 82.75 per cent efficiency with Pelton buckets were obtained, the nozzle being $^3/_8$ in. in diameter and the head 92.4 ft. Analyzing the separate losses the authors concluded that the bucket efficiency approximated 90 per cent, that the nozzle efficiency could be brought to 99 per cent, but that windage and friction losses could hardly be reduced below $3^1/_2$ per cent.

In the United States occasional patent references are available back to 1850, but in none of them is there a clear setting forth of

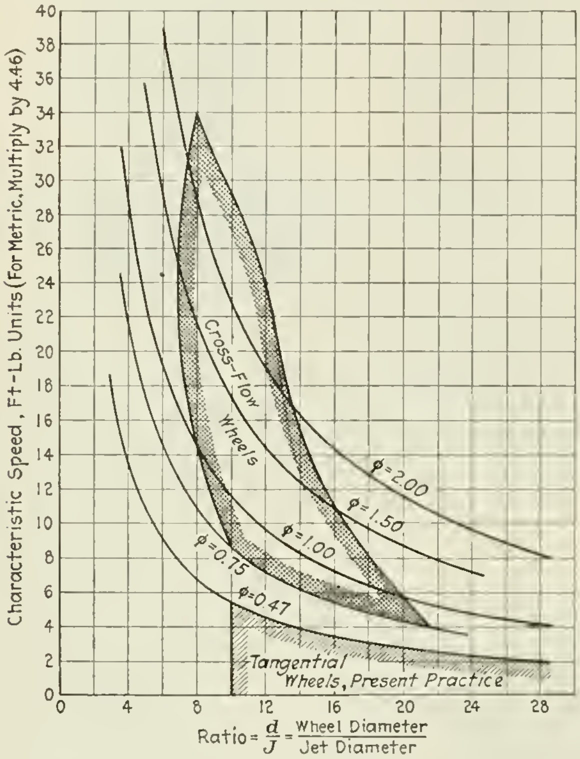

Fig. 2 Curves Showing Relation Between Characteristic Speeds of Impulse Wheels and Their Proportions as Evidenced by the Ratio d/J

(The plottings for the various peripheral coefficients indicate the increases possible with larger coefficients than are used at present. The lower shaded area indicates the approximate limits of proportions and characteristic speeds of tangential impulse wheels, and the upper area roughly the field available for development by the cross-flow wheel. The increase in characteristic speeds that is possible is quite strikingly shown.)

the reaction principle as applied to impulse wheels nor a construction suitable for applying the principles until subsequent to that date. The earliest written account is that of Atkins, who applied for patents in 1853, although issue was delayed until 1875. Apparently Atkins fully appreciated the hydraulic principles involved.

It remained, however, for the mining industry of California to produce the predecessors of the type accepted universally at present. This was perhaps inevitable as they, to probably to a greater extent than any other group of men in the world, were in daily contact with large-sized jets of water under high pressure. The first application of these jets was for the purpose of hydraulic mining, but the developing of power followed immediately. The wheels first used were known generally as the hurdy-gurdy wheels and they dominated the period from 1850 to 1870.

The development work of the period 1870–1880 is dominated by the names of Knight, Moore, Hesse, and Pelton. The origin of the present type of tangential wheel, characterized by its cup-shaped bucket for securing full reaction and by its splitter for avoiding impact losses, lies with some or all of this group of men, but Pelton undoubtedly did most to develop and commercialize this form and to him belongs the credit for first increasing the efficiency to approximately where it stands today. Later modifications were made to improve the efficiency, to avoid erosion or secure some better mechanical standard, but the inherent characteristics have so far remained unchanged.

A most interesting historical account[1] and analysis of Pelton's work is contained in the report of a Committee appointed by the Franklin Institute. This covered the various works, both European and American, leading up to Pelton's, disposed of contending claims and finally made unqualified award on the basis of simplicity, economy of maintenance, adaptability to high heads, transportability, newness, correctness of principle, and commercial importance, but above all from the standpoint of efficiency. An appended test made at the U.S. Naval Academy in 1895 by Lieutenant F. J. Haeseler, U.S.N., and Ensign W. H. G. Bullard, U.S.N., shows a maximum efficiency of 86.56 per cent with a $^3/_4$-in. jet developing only 7.756 hp., volumetric measurement of water being used. This is the type that has remained unchanged to date.

European practice starting along a divergent line during the incubation period (1850–1880) of the American designs developed the Girard axial-flow and Schwankrug radial-flow impulse wheels for high head.

Any working mechanism exposed to fluid in motion should desirably have the smallest possible hydraulic radius, that is, the least surface in contact with the water, to minimize losses and variations in velocity. For any given area the circle is the most advantageous shape as no figure has a greater area for a given periphery.

The accident of circular jets used in our western mining work was responsible for a feature of design that was very instrumental in causing the American design of impulse wheel to supersede all others. This circular-jet nozzle, later of the needle type developed by Mr. Doble, obviated pitting trouble and low nozzle efficiency (frequently as low as 85 per cent) encountered in the various forms of partial annular nozzles, square nozzles and tongue nozzles that characterized European design and were features of practically all Girard and Schwankrug wheels. Other than circular jets may work out advantageously, but so far all types of impulse wheels using them under high heads have failed or have been superseded commercially.

All impulse wheels have gradually resolved themselves into the specialized type known variously as the Pelton wheel, the tangential wheel, or more generally the impulse wheel. These have been

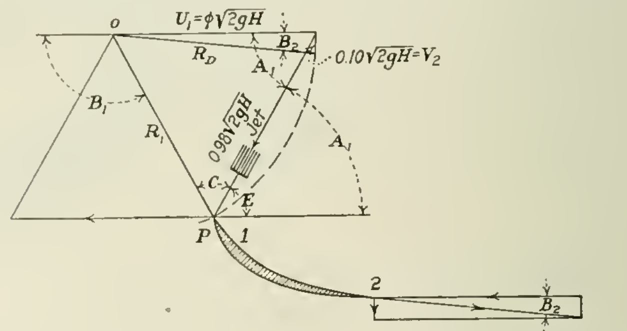

Fig. 3 Fundamental Diagram of the Impulse Wheel

(Diagram is laid out for the axial cross-flow type of wheel, but represents an average of all types, whether of radial-inward, radial-outward, conical, or axial arrangement.)

highly improved, are very simple, efficient, and reliable, and gradually all other forms of pressureless wheels have given way to them. The last to go was the Girard impulse wheel or Girard turbine as it is variously known. On account of its relatively large nozzle area it had a high characteristic speed and filled a gap not covered by either Pelton or Francis wheels except disadvantageously by the multiple-jet types of the former.

Characteristics of the Impulse Wheel

Practically all writers of hydraulic textbooks agree in their treatment of the impulse wheel that it is known by the following characteristics, the first three applying to impulse wheels in general, and the fourth identifying the present dominant type.

1 A free jet operating under the full spouting velocity due to the operating head
2 Substantially tangential application of the jet to the wheel, that is, with the major component of jet velocity along a tangent
3 A bucket velocity practically 50 per cent of the jet velocity
4 Splitter-type buckets concave on the working surfaces.

According to definition, characteristic No. 1 is inherent with

[1] *Journal of the Franklin Institute*, September, 1895.

all impulse wheels. Nos. 2, 3, and 4 dominate the impulse-wheel field at present and have done so with almost no interference for thirty years, within which period practically all the development of modern water-power machinery has taken place. During the first half of this period these characteristics covered commercial requirements which demanded the slowest-speed wheel that could be made under high heads. While certain conditions, notably high heads, still demand tangential wheels for about 15 or 20 years, the requirements of commercial practice have frequently exceeded limitations imposed by characteristics Nos. 2, 3, and 4, and to meet these new conditions the new form of wheel proposed by the author has departed from these three characteristics in a decided and radical manner.

Contrary to the general impression, the modern impulse wheel is the slowest-speed type of turbine known, although it utilizes the highest water velocities. This low-speed type has found an extensive field of usefulness by reason of its mechanical simplicity and the relatively small surface exposed to high water velocities. Its mechanical simplicity permitted the original development of this type without going beyond the capacity of carpenter's and blacksmith's tools. Its low speed was essential in connection with the small capacities and high heads to which it was adapted, as it permitted revolutions per minute sufficiently low to readily permit of direct connection with alternators of reasonable speed. Its arrangement permits elimination of clearances and packing, which involve careful design and fine machine work and are a continual source of trouble under high heads. The small

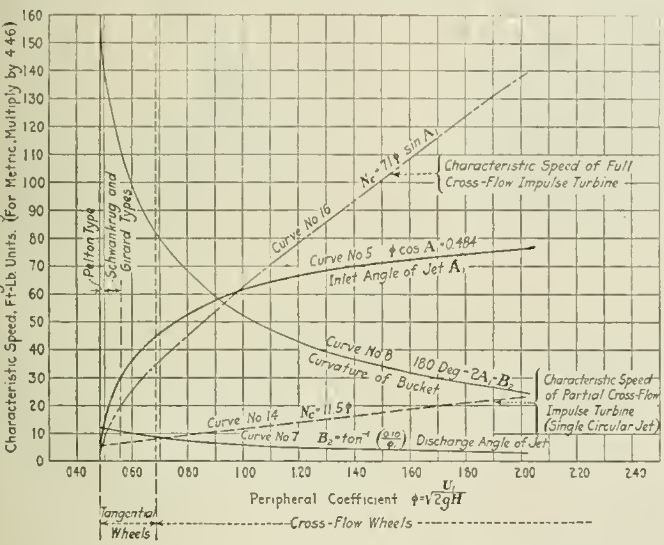

Fig. 4 Diagram of the Entire Field of Impulse Wheels, Showing the General Characteristics of Modern Tangential Impulse Wheels of the Superseded Historical Types and of the Proposed New Cross-Flow Type

(Assumptions: Discharge loss = 0.10 $\sqrt{2gH}$; jet velocity = 0.98 $\sqrt{2gH}$; overall efficiency = 80 per cent; d/J = 10.)

amount of surface exposed to water flow and the ease with which such surfaces may be inspected and renewed overcame one of the greatest problems in high-head turbine design.

It is probable that the intimate association of the low peripheral coefficient of 50 per cent with impulse-wheel design results from the fact that practically without exception authors of hydraulic treatises and writers of textbooks on the subject of hydraulic-turbine design confine themselves almost solely to this basis.

It is to this that the author takes exception, particularly since this 50 per cent basis is usually presented as a very fundamental consideration of all impulse-wheel design, whereas it really should be presented as an extreme used to permit of securing the lowest possible bucket speed. A single glance at the complicated forms of the most noteworthy impulse-wheel installation of the last few years should be all that is needed to indicate to the unbiased engineer whose ideas have not already been prematurely and positively fixed along a certain line, that the desirability of low speed in the buckets of these units has long since passed. The unit of Fig. 1 illustrates this point, as do also all of the record capacity units above 5000 hp. or since 1904.

So far as water velocity is concerned, the impulse type of wheel should have the highest speed of any type of turbine, except those which may be classed within the so-called "suction" field. The water velocity in the usual reaction wheel (Francis) seldom exceeds 50 to 75 per cent of the spouting velocity, or the same percentage of that which holds in all impulse practice. The main reason for the low characteristic speed of impulse wheels is found in the fact that the whole periphery of the Francis is utilized for developing powers, whereas the usual impulse wheel comes under the classi-

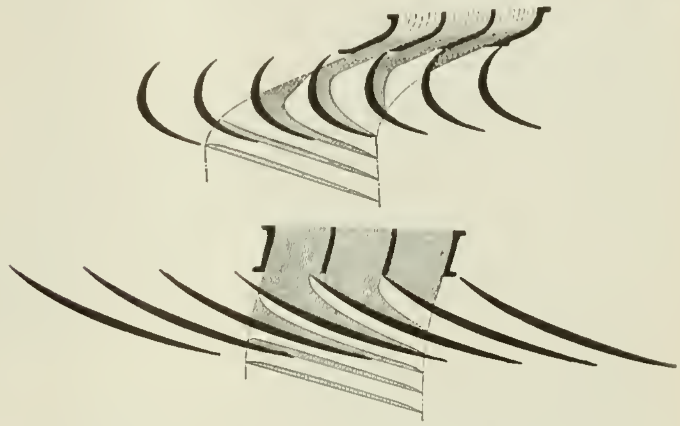

Fig. 5 Diagrams Illustrating the Relatively Smaller Portion of the Periphery of a Wheel Utilized by a Given Jet of the Cross-Flow Type as Contrasted With That of the More Nearly Tangential Flow. The Possibility of Utilizing a Larger Number of Jets Without Interference is Evidenced

fication of partial turbine. The result is that in comparing on the basis of a certain hp. the diameter of the impulse type becomes so large that its r.p.m. is unduly reduced. This is further emphasized by the fact that the reaction wheel usually runs with a coefficient of rim velocity in the neighborhood of 60 to 90 per cent as contrasted to the 50 per cent for the present impulse type.

Speeds of tangential impulse wheels cannot be increased by reducing their diameter beyond a certain limit illustrated in the lower curve of Fig. 2, because the bucket turns so abruptly out of the working path of the jet. The relationship between the characteristic speed of the tangential impulse wheel and its ratio of wheel to jet diameter illustrate the approximate limitations of commercial practice. Exceeding the ratios indicated simply means that there will be what is called "racing water," with its inherent loss of efficiency.

Unit capacities have so grown that for a considerable period, possibly for the last 15 or 20 years, strenuous efforts have been made to increase specific speeds of impulse units. As is usual in such cases, human inertia has been such that the new need was not recognized, the result being that the art of impulse-wheel design went through the same evolution as did that of reaction-type turbines, i.e., multiplicity of runners, nozzles, etc., without attacking the fundamental element of relative bucket velocity or direction of jets on the wheel to avoid interference. The orthodox 50 per cent velocity of bucket and tangential application of jet with its large consumption of wheel periphery were and still are the dominant factors of the impulse units of even recent manufacture and of all engineering textbooks on the subject.

Experimental Work of the Author

During the years 1913 to 1918 the author was experimenting almost continually with flat-angle runners of the axial-flow type. This work resulted in the development of the high-speed suction type of propeller runner since applied extensively to low heads and led to an appreciation of the characteristics necessary to high speed in any vane moving in a fluid. In his paper describing this work before the A.S.M.E. in December, 1919, the following statement was made as covering any water wheel, the ice boat illustration incidentally coming under the classification "impulse" as defined herein.

Neglecting friction and possibly blade thickness, there are no mathematical or hydraulic laws that will prevent doubling or quadrupling any particular characteristic speed by simply flattening the blade angles.

A direct analogy to this is the well-known illustration of relative velocities evidences in the sail of an ice boat.

Continuing this work on high-speed runners with impulse wheels, the author in company with J. F. Roberts experimented with small-angle single-lobe types of buckets with the jet making small angles with the tangent. The purpose was to secure an arrangement whereby more jets might be used on a single wheel without interference and to eliminate the splash losses resulting from water discharged upward and falling back on the wheel in vertical shaft arrangement. The result was difficulty from the "backed" water indicated at B in Fig. 6, which was one of the causes of the low efficiency and pitting that contributed largely to the commercial failure of Girard wheels and other single-flow impulse turbines. In playing jets from an ordinary garden hose on small models of these wheels that were running at a high rate of speed (10,000 to 20,000 r.p.m.) a decided change in their tune was noticed with various positions of the jet. On account of ease in construction one of the wheels happened to have been cast without back curvature of buckets, similar to the propeller-type suction runner. With this wheel the highest pitch or note was developed with the jet directed almost perpendicular to the plane of the wheel. This was so contrary to fundamental impulse practice as indicated by all commercial installations built in recent years and covered in any treatise on hydraulics that it attracted instant attention. Analysis of the condition resulted in a series of diagrams such as Fig. 3, and these worked naturally into the following algebraic analysis.

Let—

$$\text{Jet velocity } V_1 = 0.98\sqrt{2gH}$$

From the right triangle on base OE

$$R_D = \sqrt{U_1^2 + V_2^2}$$

and from the law of cosines

$$R_I = \sqrt{V_1^2 + U_1^2 - 2V_1U_1 \cos A_1}$$

But $R_D = R_I$,

$$\therefore U_1^2 + V_2^2 = V_1^2 + U_1^2 - 2V_1U_1 \cos A_1$$

whence

$$\phi^2(2gH) + 0.01(2gH) = 0.96(2gH) + \phi^2(2gH) - 2\,\phi \times 0.98(2gH) \cos A_1$$

and (see curve 5, Fig. 4)

$$\phi \cos A_1 = 0.484 \qquad [1]$$

Note that varying the assumption of $0.10\sqrt{2gH}$ discharge loss has very little effect on the inlet angle.

For the average impulse wheel the bucket inlet angle is practically twice the jet angle, that is (see curve 6, Fig. 4),

$$B_1 = 2A_1$$

Proof:

$R_D = R_I$ since relative velocities are practically constant in an impulse wheel (exactly so in axial flow).

$R_D = OE$ (Fig. 3) very closely since B_2 is always very small. Exact equality could be attained by allowing a slight forward component.

$OE = OP$

$\therefore$ Angle C = Angle A_1

But $A_1 = E$ by construction and $C + E = 2A_1$

$\therefore B_1 = 2A_1$

$$B_2 = \tan^{-1}\left(\frac{0.10\sqrt{2gH}}{\phi\sqrt{2gH}}\right) \text{ from right triangle}$$

$$= \tan^{-1}\left(\frac{0.10}{\phi}\right) \qquad [2]$$

$$\text{Bucket curvature} = 180° - B_1 - B_2 = 180° - 2A_1 - B_2$$

$$= 180° - 2\cos^{-1}\left(\frac{0.484}{\phi}\right) - \tan^{-1}\left(\frac{0.10}{\phi}\right) \qquad [3]$$

(See curve 8, Fig. 4.)

With impulse wheels simple relationships may be deduced for comparative purposes as follows, letting J = jet diameter or thickness and d = wheel diameter, both in feet.

The equation for the characteristic speed of the wheel is—

$$N_c = \frac{\text{r.p.m.} \times \sqrt{\text{hp.}}}{H^{5/4}} \qquad [4]$$

and the speed is

$$\text{r.p.m.} = \frac{60\,\phi\sqrt{2gH}}{\pi d} \qquad [5]$$

Assuming 80 per cent efficiency and one circular jet per wheel,

$$\text{hp.} = \frac{\pi J^2}{4} \times \frac{0.98\sqrt{2gH} \times H \times 62.4 \times 0.80}{550} = \frac{J^2H^{3/2}}{1.78}$$

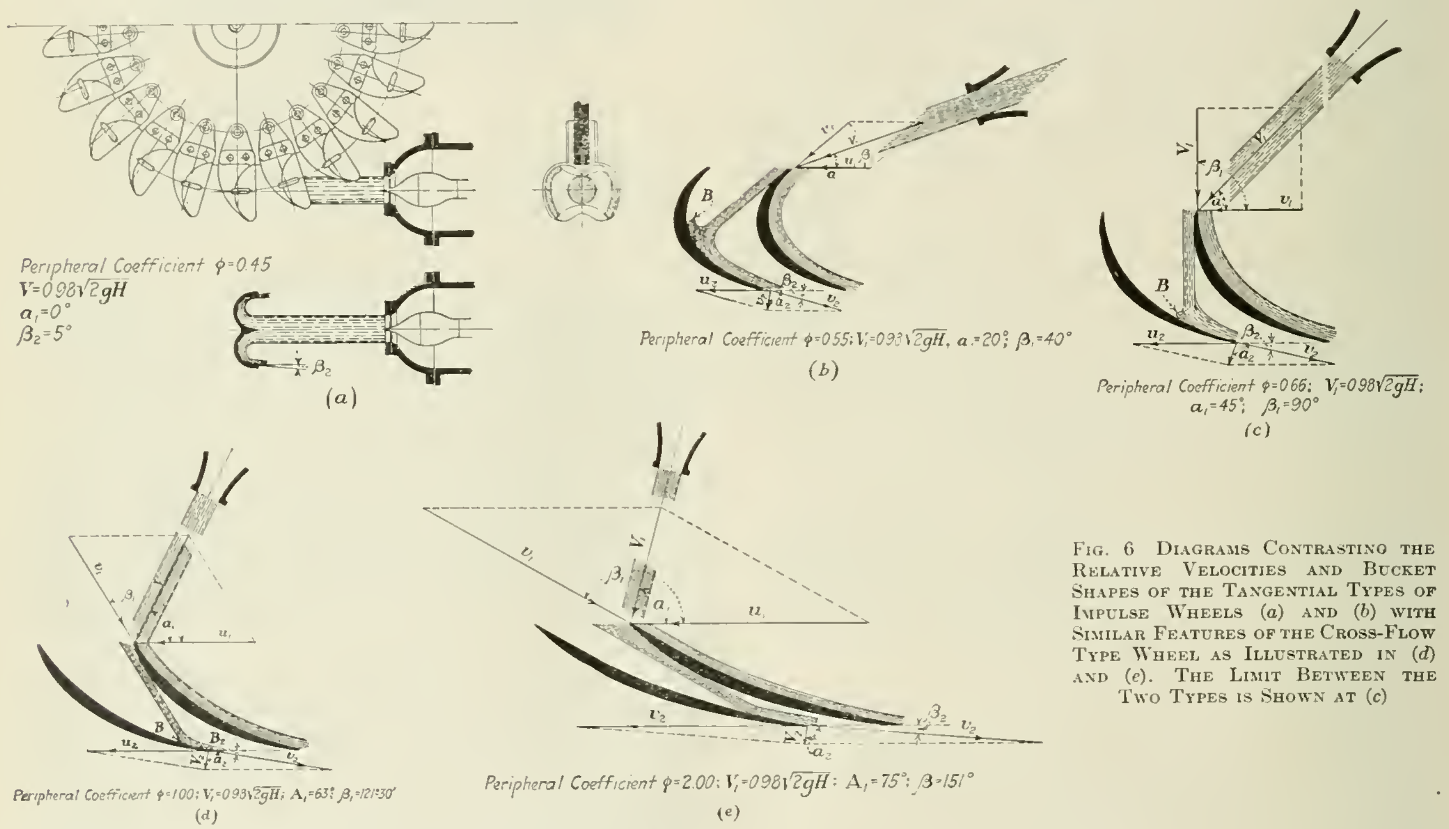

Fig. 6 Diagrams Contrasting the Relative Velocities and Bucket Shapes of the Tangential Types of Impulse Wheels (a) and (b) with Similar Features of the Cross-Flow Type Wheel as Illustrated in (d) and (e). The Limit Between the Two Types is Shown at (c)

and

$$\sqrt{\text{hp.}} = \frac{JH^{3/4}}{1.335} \quad \ldots\ldots\ldots [6]$$

Substituting [5] and [6] in [4] gives

$$N_c = \frac{115\ J\phi}{d} \quad \ldots\ldots\ldots [7]$$

Most engineers dealing with the subject are familiar with Equation [7] expressed for tangential wheels as

$$N_c = 55\frac{J}{d} \quad \ldots\ldots\ldots\ldots [8]$$

ϕ being taken as equal to 0.48.

Modern tangential impulse wheels preferably have a ratio of wheel diameter to jet diameter of 12 to 14, with 10 as a desirable minimum. Using the latter value for comparative purposes,

$$N_c = 11.5\ \phi \quad \ldots\ldots\ldots [9]$$

for impulse wheels with single circular jets (see curve 14, Fig. 4).

With multiple jets the limit of characteristic speed is reached with a solid annular jet of width J or when the nozzle area is πdJ. In this case, assuming 80 per cent efficiency,

$$\sqrt{\text{hp.}} = \frac{2H^{3/4}\sqrt{dJ}}{1.335}$$

which, substituted with [5] in [4] gives

$$N_c = 225\ \phi\ \sqrt{J/d}$$

neglecting for the moment the jet angle; and for the d/J ratio of 10 assumed above,

$$N_c = 71\ \phi \ldots\ldots\ldots\ldots [10]$$

Since the full annular area of the nozzle is not effective on account of the inlet angle of the jet expressed in [1], Equation [10] must be altered to read

$$N_c = 71\ \phi\ \sqrt{\sin A_1}$$

(see curve 16, Fig. 4), since the quantity and consequently the hp. vary as the axial or radial component and N_c varies as $\sqrt{\text{hp.}}$

The significant relationship between wheel speed and jet angle is shown perfectly in Equation [1], the graphical showing being curve No. 5 of Fig. 4.

Considering the fact that this relationship is based on the fundamental requirements of an impulse wheel, i.e., low exit loss and constant relative velocity (resulting from no change in pressure) in the bucket itself, the curve may be used for some very broad conclusions. The main one is this:

Speed in impulse-wheel work is a function of the angle the jet makes with a tangent.

If the jet angle is zero as in accepted present practice, the speed, which is a function of ϕ, is the lowest that can be obtained without preventable loss. As the angle of the jet increases to 45 deg. the relative wheel velocity increases from 50 per cent to only 69 per cent of the jet velocity. From this point, however, the most radical increase is effected. For example, from a 69 per cent coefficient at 45 deg. the speed increases to 100 per cent at 61 deg. This feature combined with the obvious departure from the tangential flow of present practice led to the following designation of two classes of impulse wheels accordingly as the major component of the jet velocity is along or normal to the tangent:

Tangential Impulse Wheels—Jets making angle less than 45 deg. with tangent.
Buckets decidedly concave, curvature greater than 90 deg.
Bucket inlet inclined backward.

Cross-Flow Impulse Wheels—Jets making angle greater than 45 deg. with tangent.
Buckets flattened, curvature less than 90 deg.
Bucket inlet inclined forward.

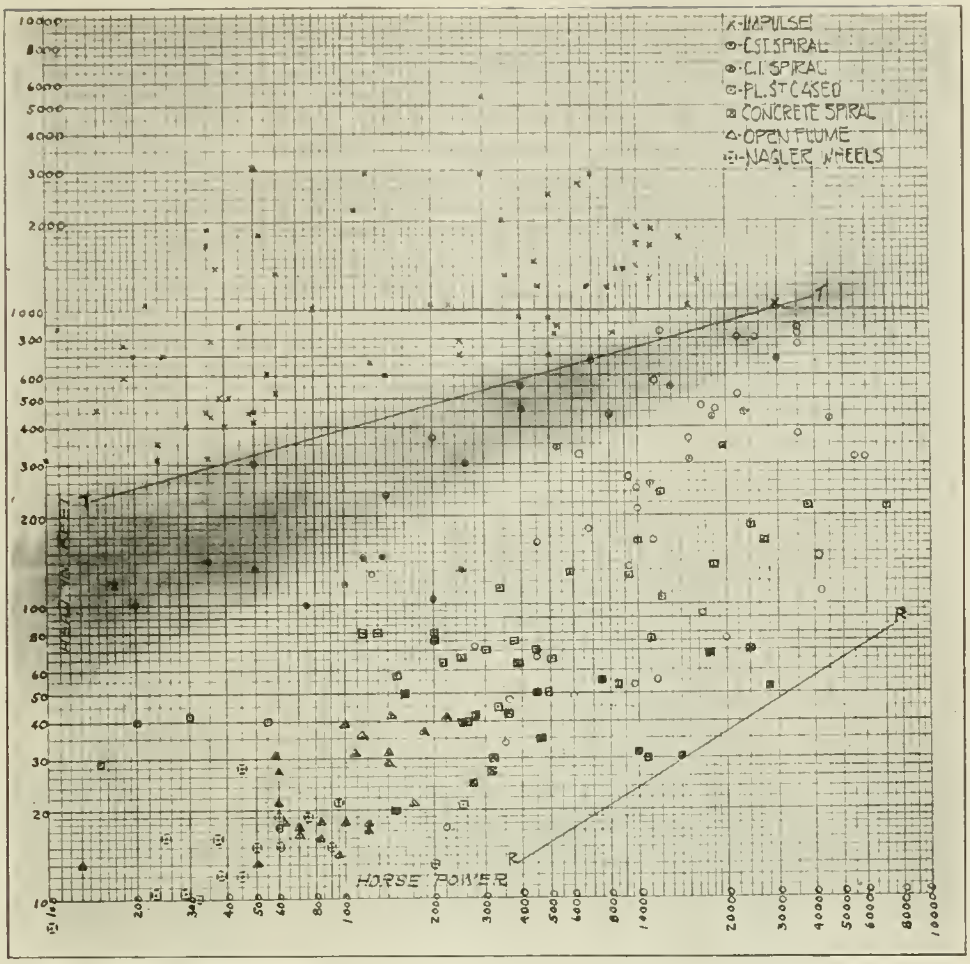

Fig. 7 A Plotting of the Entire Hydraulic-Turbine Field, Embodying Practically All of the Noteworthy Plants Ever Built

(Points above line T-T represent impulse units, practically all of them being of the tangential type. Line R-R represents approximately the limit of reaction units. The shaded portion adjacent to line T-T represents a field lying between the tangential impulse and high-head reaction fields and at present disadvantageously developed by them. This is the field to which the proposed cross-flow type of wheel is particularly adapted. Impulse-wheel horsepowers are plotted for one jet.)

The name "Cross-Flow" was selected after considering such terms as "vortex impulse" or "annular impulse" (on account of the ease with which so many jets may be used as to form a continuous whirling jet); and "axial impulse," "radial impulse," "mixed-flow impulse," etc., for reasons connected with the noticeable feature of various mechanical arrangements. "Cross-flow" seemed especially appropriate not only because it so aptly describes the direction of flow across the wheel but because it so distinctly defines the direction of flow as contrasted to that in the present wheels which are universally known as the tangential type.

Advantages of the Cross-Flow Type of Impulse Wheel

The cross-flow wheel, aside from its advantage in speed, automatically corrects one of the defects that contributed greatly to the failure of single-flow impulse turbines such as the Girard and other partial wheels. The "backing" of water in the wheel resulting in its being dragged around with the wheel and ultimately discharged at wheel velocity at about half its original velocity, results from impact due to the large angle between the relative water path and the surface of the bucket at the point of impact [point B, Fig. 6 (b)]. The slower the speed of the bucket, the greater the curvature and consequently the greater the impact and "backing" loss.

With higher speeds the bucket becomes flatter and the "backing" loss with its poorer efficiency and greater tendency to pit is more and more reduced [see B, Fig. 6 (d)] without resorting to the undesirable expedient of increasing the number of buckets. Inspection of the successive diagrams of Fig. 6 indicates how the angle of impact between the jet and bucket is successively reduced as the speed is increased and the bucket correspondingly flattened. The author believes that this principle can be utilized to eliminate

or at least reduce the efficiency losses and pitting troubles experienced with the Girard types, and with it there will be a rapid return to radial and axial and even conical or mixed-flow impulse wheels. In combination with nozzles designed to deliver circular jets with their higher efficiencies and more uniform distribution of velocities cross-flow wheels can be applied to a considerable portion of the field for which there is at present no design except the disadvantageous multiple-runner or multiple-nozzle types. For low heads and small powers or where efficiency may not be of the greatest importance the circular jet may be dispensed with and rectangular jets arranged to partly cover the wheel periphery (partial turbines), or even solid annular jets (full turbines) may be utilized.

The cross-flow wheel does have an inherent disadvantage from an efficiency standpoint. The relative velocity between jet and bucket is the lowest (50 per cent of spouting velocity) in a tangential wheel and higher in the cross-flow types; for example, for a 100 per cent coefficient the relative velocity is practically twice what it is in a tangential wheel. This, of course, involves a greater friction loss, but in actual practice this may be offset by reduction of windage and splash losses and particularly by the possibility of developing more power in a given working volume of space swept by the buckets than it is possible to do with the tangential type (see Fig. 5).

Vertical impulse wheels have certain mechanical advantages when large capacities are considered, these being similar to those which underlie the popularity and economies of the vertical reaction units and in addition incorporate the possibility of feasible mechanical arrangement of more jets than possible with horizontal types. Engineers experienced with impulse work, however, are familiar with the tremendous disturbances that exist even in horizontal wheels having but a single jet and can appreciate the condition that must exist when several jets are played on one wheel. When it is further considered that all the upwardly discharged water that falls or is spattered back into the path of the buckets must again leave the wheel at practically wheel velocity or half its own initial velocity, and that this represents a total loss, the desirability of getting the water positively and clearly away from the wheel is apparent. The cross-flow design, embodying as it does the feature of single direction of flow through the wheel without "backed" water losses, lends itself admirably to this arrangement. This is particularly so as in extreme cases multiple or annular jets may be used without injurious interference, as each elemental jet uses such a relatively small portion (see Fig. 5) of the periphery as contrasted to the tangential type where each jet needs for its working space a chord subtending a relatively larger angle.

Fig. 7 presents the entire field of hydraulic-turbine practice. On this diagram are plotted the heads and horsepowers of practically every water wheel of note ever built, particularly those that extended the developed field in any direction, regardless of type or nationality. The upper field above the line *T-T* (points marked ×) are of the impulse type. Those below the line *T-T* are of the reaction (Francis or suction) types. Portions below, to the right, or above the limits of the field of plotted points are as yet undeveloped.

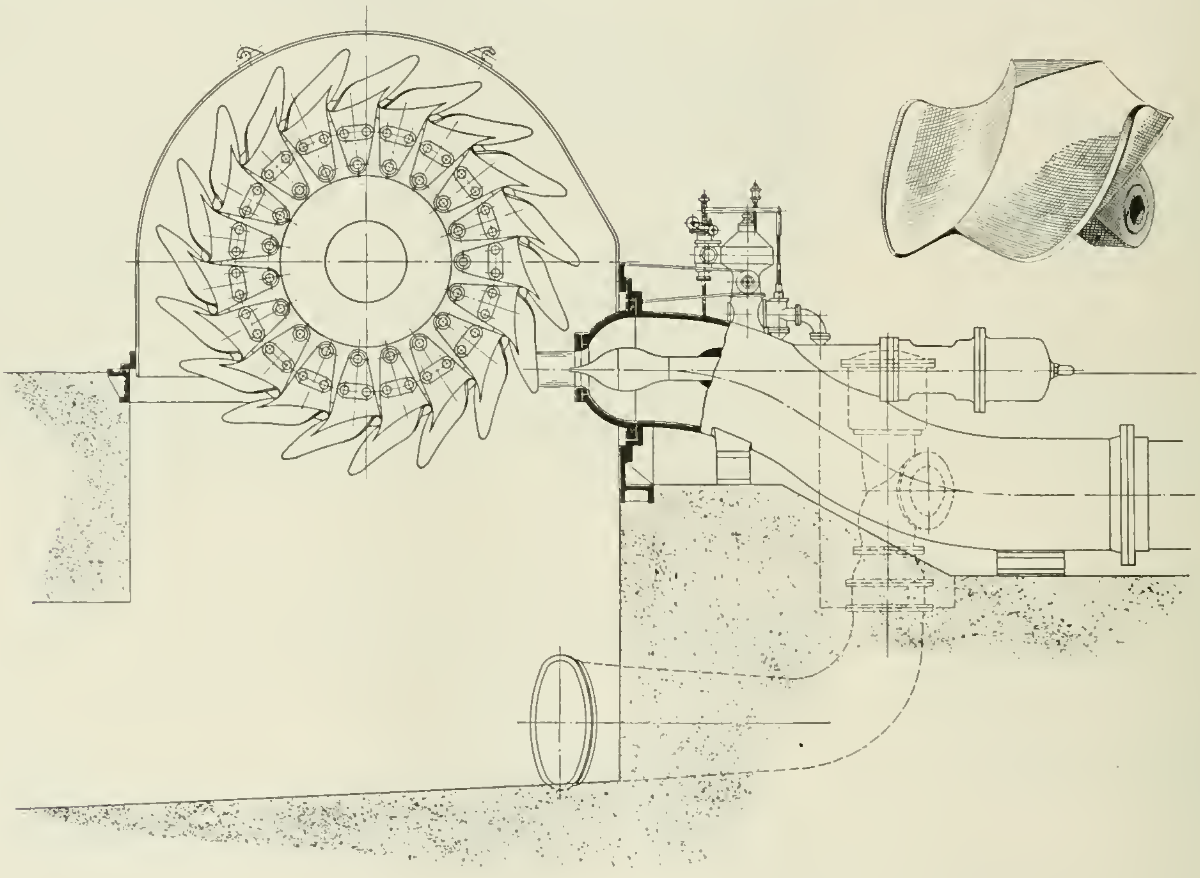

Fig. 8 Suggested Application of the Cross-Flow Principle to an Impulse-Wheel Unit of Conventional Arrangement

(The large angle of incidence shown is obtained by simply raising the jet above a tangential line so that it flows in a more nearly radial direction. The sketch at the upper right of the figure shows a bucket for use with a cross-flow wheel and designed to illustrate dividing the discharge and equalizing the thrust by a splitter.)

Undesirably low generator speeds have so far restricted further development below and to the right of the line *R-R*. Size of parts and transportation limitations retard although do not prohibit extension to the right above the line *R-R*. The infrequency of points at the top of the sheet arises from the difficulties arising from extremely high pressures (above 3000 ft. for example), the difficulties in securing suitable material for withstanding high stresses, and the comparative infrequency with which such high-head conditions are encountered. Undoubtedly the next few years will see units of 100,000 hp. capacity, and possibly more heads in the neighborhood of 3000 ft. 70,000-hp. impulse units for 2150 ft. head are even now being worked out in detail.

The significance of Fig. 7 so far as this paper is concerned lies in the comparatively undeveloped gap existing between the impulse and reaction types. This gap exists by reason of the difference between the highest impulse characteristic speed (about 5 ft-lb. units) and the lowest reaction characteristic speed (about 10). Even the multiplication of jets and nozzles incorporated in

most of the larger-capacity impulse units has failed to bring the two fields together.

The field of head and capacity now covered by impulse wheels of the tangential type needs extending only a limited amount. This extension is indicated roughly by the shaded section of Fig. 7, this section lying along and below the line *T-T*, between the fields to which tangential impulse and reaction wheels are well adapted. Going beyond this neutral ground in a lower direction, involves competition with the reaction-type runners that give economical generator speeds with lower water velocities and better efficiencies. It is to this intermediate field that the cross-flow impulse design is peculiarly adapted, as with it characteristic speeds of 5 to 20 are readily obtainable with single jets as shown in the upper shaded area of Fig. 2 and curve 14 of Fig. 4. With multiple or annular jets even higher speeds are possible, theoretically up to over 100 from curve 16, Fig. 4. There will probably be no commercial demand for such extreme speeds using the cross-flow principle as the reaction type covers this field satisfactorily and with more desirable water velocities. The greater simplicity of the impulse type may, however, make those high-speed types work out advantageously with small or auxiliary units.

As in all simple developments, a detailed search of prior art shows numerous designs that might be construed to anticipate the cross-flow principle. These comprise various designs from the earliest forms of flutter wheel where water from a trough falls on a paddle wheel, up to and including various forms of Jonval wheels, which may have been set above tail water, and through the various designs of Girard and Schwankrug wheels. All of these installations with which the author has been familiar have a flow other than tangential, not by reason of its advantage but because of certain desired mechanical arrangements and in spite of the acknowledged disadvantage of departing from the tangential arrangement. This fact is indicated by the numerous details of design which indicate the extreme measures which were used to secure flow as nearly as possible tangential. Exhaustive search has indicated no single instance where free circular jets, adjustable in size, have been purposely directed against the buckets at angles greater than 45 deg. with a tangent.

That the problem of securing higher specific speed in the impulse field is one of real commercial significance is indicated by the fact that such variety of expedients have recently been used to raise speeds. These efforts parallel with surprising exactness the multiple-runner craze that dominated the reaction field during the years 1900 to 1910, resulting from the attempts of water-wheel builders to keep pace with electrical designers in speeds of units. The reaction program was confined at first to using multiple runners, as the entire periphery was used at the start. Later the reaction development followed lines of widening the inlet to the runner, increasing the velocity of the water, and finally in increasing the relative wheel velocity.

The impulse-wheel designer started with the limit of water velocity, has gone through the stages of multiple jets, then multiple wheels, and is now at the point of facing the use of larger percentages of wheel periphery (larger inlet area) and higher wheel speeds.

The analogy to the history of reaction-wheel development is perfect, even to the point where for a large field of head and capacity the electrical designer is ahead of the wheel designer in speed. With the development of high-speed impulse wheels there should be experienced a return to the single wheel and possibly to the vertical shaft setting, the two features that so completely dominated the tremendous advances experienced in the reaction field in the past decade.

This does not mean that the tangential wheel is to be displaced, rather that it should be supplemented. For a certain range of head and capacity—a very wide range at that—it affords a perfect solution, one that harmonizes with desirable generator speeds with excellent efficiency and the utmost simplicity and durability.

It is for lower heads and larger capacities that new designs are needed. While the elements of the machines themselves are not subjected to mechanical complication or hydraulic losses as serious as those which caused the multiple-runner reaction turbine to be superseded by the single vertical arrangement, the general complications of water passages and governing mechanisms and possibilities of flow interference are certainly such as to be expensive and undesirable. If the history of the progress in reaction wheels is any guide, future developments in the impulse field will return to single runners of higher characteristic speeds just as the multiple-runner reaction wheels yielded first to higher-speed mixed-flow wheels and later to the still higher-speed axial-flow or suction wheels.

Fig. 8 is shown as an example of proportions and possible details of a unit based on the cross-flow principle for conditions of reduced head and increased capacity comparable with those which incur multiple jets or wheels. This is shown as indicating a possible trend in impulse design based on investigation of modern commercial needs and analysis of the hydraulic and mechanical features involved. It is not suggested that initial installations should be made for such large capacities and heads without first obtaining more operating data than are now available on the new type proposed. It is believed, however, that the low-head extension of the field of impulse wheels, particularly for small and moderate capacities, is warranted immediately.

The main purpose of this paper is not to present a complete solution of problems confronting the designer of impulse wheels, nor is it intended even to present the new type as being completely worked out. It is intended to draw attention forcibly to the possibility of departing from the orthodox tangential flow and 50 per cent coefficient, departing even from the specter of practice, precedent, usage, and textbooks without violating perfectly sound hydraulics. If the only too common tendency to get in a rut and stay there is lessened, the author will be more than satisfied.

Power from Tides

THOSE interested in power generation from tides might do well to read Hydro-Electric Engineering, vol. 2, edited by A. H. Gibson (compare review in *Engineering*, Feb. 16, 1923, p. 193).

In the simplest manner the author states the principles on which alone a scheme can prove a commercial success, and he is under no misapprehension as to the difficulties that any proposal will have to face and overcome. He submits the loose and somewhat optimistic views of irresponsible guides to the stern arbitrament of actual statistics drawn from the published balance sheets of Canadian companies, who have had the advantage of acquiring land at prairie value, and little to fear in the way of active competition. It is idle to point out that the nation is allowing a valuable asset to run to waste by neglecting tidal movement while the coal fields are being extravagantly depleted, unless it is explained how that force is to be utilized. At present there is no market for such power; only new undertakings can utilize the energy, and there are but few signs of these forthcoming.

Apart from the commercial success there are, however, many interesting problems that arise in considering the novel scheme of harnessing the tides. Some of these, more particularly concerned with hydraulics, were discussed in the earlier volume. Dr. Gibson now carries the inquiry a stage further. Matured reflection has convinced him that multiple-basin systems must be excluded as outside the limits of practicability, and that the only schemes likely to lead to a successful issue must be based on the use of a single basin developing power on both rising and falling tides, or on the outflowing tide only. Assuming that the tidal basin has an area of 1 sq. mile, that the water surface is sensibly level at all stages of the tide, that the range at spring tides is 42 ft., that 5 hr. are occupied in rising and 7.5 in falling, that at neap tides the range is 16 ft., and that the time consumed in rising equals that in falling, it is possible to form a very definite idea of the power that would become available. Three cases may be considered: First, working on a falling tide only—the least favorable case—and making the usual allowance for loss in storage supply, the output may amount to 7680 b.hp. continuous 24 hr. working. In the second case, operating on rising and falling tides under natural head, the output rises to 12,400 b.hp. Finally, if the scheme be arranged to work with rising and falling tides with constant rates of rise and fall in basin, a maximum output of 13,150 b.hp. is attained if all the energy is absorbed. In these estimates it is assumed that the primary turbines have a mean efficiency of 75 per cent, but this value may be too high, for under the extreme variations of head the efficiency of any constant-speed turbine falls off rapidly.

Lignite Char: Its Production and Possibilities

By O. P. Hood,[1] Washington, D. C.

Lignite char is lignite which has been dried and distilled in an oven especially designed for the purpose. About two and one-half tons of raw lignite reduce to one ton of char, the heating value of which is about 12,000 B.t.u. per lb. While raw lignite can be used satisfactorily in large steam-raising operations the author believes that the search for a means to improve the fuel must continue. American lignites do not briquet well without the addition of a binder, and the Bureau of Mines has therefore been led to investigate the possibilities of an inexpensive carbonizing process and the use of the resulting lignite char direct without briquetting. This process is briefly described in the paper.

The greatest difficulty with our lignite is the fact that in nearly every district where it should be the natural fuel it is put in competition with high-grade fuel. We are all spoiled by having been blessed with an abundance of the best, so that we are impatient with the limitations of lower-grade fuels. If we had been obliged to go down 2000 ft. or more and win good coal from thin seams in scattered districts as they do in Europe, we would have long ago worked out a successful technique for utilizing our lignites. Canadian and North Dakota lignite must compete with anthracite and with Pittsburgh and Illinois bituminous coal; our Texas lignite must compete with gas, oil, and Oklahoma bituminous coal. It is evident, however, that there must be a price at which the lower-grade fuel will begin to be attractive. In round numbers the ratio is somewhere in the neighborhood of half the price of good coal. With the rising price of bituminous coal we are fast approaching the time when this ratio will be common.

The handicaps of lignite are well known, but not always properly valued. The heating values of high-moisture fuels are somewhat misleading. The heat carried by the moisture is recovered and measured in the calorimeter, but is not fully utilized in a boiler furnace. The B.t.u. ratios, therefore, do not give the relative possible steaming values of the fuels if comparison is made between a high-moisture lignite and a low-moisture bituminous coal. Although the ash percentage may be low, there is usually a larger total amount of ash to handle in a plant using lignite. The fusing temperature of the ash is usually low, making high rates of combustion difficult and requiring larger grate areas and furnace volumes than with higher-grade coal. Notwithstanding these handicaps, with present technique, raw lignite can be used in large operations, and good efficiencies and reasonable capacities can be obtained. The problem is largely an economic one. When raw lignite is cheap enough in comparison with better coals it will be used in large steam-raising operations.

Improvement of Raw Lignite for Fuel Purposes

The search for a means to improve the fuel, however, must continue. A fuel classed as lignite in northern Bohemia, and weathering much as does our lignite, is as carefully prepared for market as is our anthracite. Seven prepared sizes are offered to the market. Raw lignite can probably be somewhat improved for steam raising by sizing the product more closely than is common practice. It is probable, however, that an improved lignite product must first cater to a special trade that will pay a special price. This is illustrated by the vision that has been so frequently held of improving the lignite by some process involving briquetting. Unlike the German "Braunkohle," our lignites do not make a stable and satisfactory briquet simply by drying the lignite and briquetting by heat and pressure. They lack sufficient inherent binder to consolidate and waterproof the mass. The necessary added binder increases the cost and hardly improves the quality. A quite satisfactory fuel can, however, be made by briquetting lignite char, and it is probable that some day such a fuel will be in common use.

There have been hopes that through the recovery of by-products sufficient credits might be obtained to materially lessen the cost of briquets. Profit can be shown on paper, but such a process is essentially a large-scale operation requiring a large investment and very substantial financial backing by those familiar with technical enterprise. It is difficult, therefore, to start such an industry, for there is no opportunity to begin small and grow up, returning profits into an improved plant. Capital familiar with technical enterprise finds less hazardous ventures, and capital unfamiliar with such enterprise is apt to be misled and lost.

Lignite Char and Its Possibilities

With these facts in mind, the United States Bureau of Mines is investigating the possibilities of a somewhat different program which has for its main features an inexpensive carbonizing device and the use of the lignite char direct, without briquetting. If a market for the char can be developed, and the small mine can produce char, there would be provided means for a natural evolution of an industry that in time might realize the larger vision of briquetting and recovery of by-products. Lignite char can best be described in a few words as a fuel rather near in analysis to anthracite coal, but softer, with a little more volatile matter, and thus kindling easier. In size it grades from pea coal to smaller sizes, and is a stable product. Whether a market can be developed for such a fuel at prices around five dollars a ton at the mine, remains to be shown, but it is at least encouraging to know that Germany used last year 400,000 tons of similar material for domestic heating and cooking. This fuel burns well with natural draft where a thin fuel bed, about $1^1/_2$ in. in thickness can be maintained. Base burners, cook stoves, and other heaters can be adapted to use the fuel satisfactorily. The Germans have developed a special stove, burning the fuel on a bed of ash in an enclosed drawer. There is no loss of fuel in the ash and our lignite char used in such a stove heats an oven sufficiently for baking operations and will boil water. It makes a very clean fire, is smokeless, and the char is clean to handle. It is, however, slow in getting under way as compared to a gas range.

Production of Lignite Char

To produce the char a very simple oven has been devised that greatly reduces the investment from that needed for ovens heretofore proposed. If lignite be passed through a combustion zone, moisture is first driven off; then combustible gases are distilled, and finally the solid carbon is burned. There is a considerable shrinkage in volume and a complete absence of caking quality. These steps are fairly distinct one from the other, so that the flow of lignite through the combustion zone may be so regulated that but little of the fixed carbon is burned. The combustion zone can be maintained by burning some of the distilled gases within the moving mass of lignite, and such direct heating is more efficient than where heat must be transmitted through refractory walls. The hot gases of combustion also pass through the mass, driving off the moisture and departing fairly cool. It is something like an open-top lime kiln. The process has proved simple and efficient. Of the gas driven off, much of it is used in the combustion zone, and in addition, less than 5 per cent of the weight of the original lignite is burned. That is to say, the fixed-carbon loss in the process for drying and distilling is lower than is usually found for drying alone where separate driers are used. Passing the combustion zone the lignite enters a lower section protected from the air, where it cools and is then removed. The char obtained by such a process may, of course, be briquetted.

An oven of this sort was operated at Grand Forks, North Dakota, during the past summer, and about 400 tons of various North Dakota lignites passed through. In February about 100 tons of Saskatchewan lignite was tried to discover whether this presented any special problems.

About two and a half tons of raw lignite reduce to one tone of char, and the heating value is about 12,000 B.t.u. per lb. The moisture is very low, and the char can be stored without danger of fire or degradation in size. Where the freight charge is heavy it would be an advantage to ship char instead of raw lignite.

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[1] Chief mechanical engineer, U. S. Bureau of Mines, Mem. A.S.M.E.

Contributed by the Fuels Division for presentation at the Spring Meeting, Montreal, P. Q., Canada, May 28 to 31, 1923, of The American Society of Mechanical Engineers. All papers are subject to revision.

Aluminum Bronze as an Engineering Material

By W. M. Corse,[1] Washington, D. C.

By aluminum bronze is meant, not the gray-white metallic coating used on radiators, but rather a strong, reliable metal resembling 0.35 per cent carbon Swedish bessemer steel to a remarkable degree. The color, of course, is different, but the mechanical properties are much the same. It resists alternations of stress unusually well and is superior to nearly all of the non-ferrous alloys except monel metal in this respect. Aluminum bronze is essentially 90 to 92 parts of copper and 8 to 10 parts of aluminum, while monel metal is approximately two parts of nickel to one part of copper. Naturally, the two metals behave differently with respect to corrosion, but they are much alike in strength and hardness. Both hold their strength much better than other alloys when exposed to elevated temperatures, a fact of importance to the steam engineer.

Properties

Aluminum bronze is about the color of 10-carat gold, has a tensile strength of 70,000 lb. per sq. in., and an elongation of 15 per cent. Its Brinell hardness number is 100–110. These properties place it in the class of strong bronzes suitable for the most exacting service. Particular mention should be made of its resistance to alternating stress or fatigue. "In the Landgraf-Turner endurance-testing machine the aluminum bronzes resisted 4500 blows before fracture, while the manganese bronze resisted about 500."[2]

"The results show clearly that aluminum bronze, in spite of its comparatively low yield point and proportional limit as shown in a tension test, is far superior to manganese bronze in endurance of alternating stresses or resistance to fatigue, and therefore its life would be longer in practical use."[3]

Similar comments were made by the authors of the Eighth Report to the Alloys Research Committee of the British Institution of Mechanical Engineers. Many practical tests have confirmed all of the above statements, so that an engineer in search of a metal to withstand fatigue should consider aluminum bronze. Such parts as those for air hammers and foundation bolts for drop hammers are good examples.

The other strong bronze, manganese bronze, has many admirable properties, but it is not adapted for bearing surfaces. Aluminum bronze has proved its worth in this field in such parts as worm-wheel gears. Every day's output of 1000 Ford trucks carries 12,000 lb. of this metal in gears. Extensive tests of aluminum-bronze gears against phosphor bronze in one-man tanks during the war proved the superiority of the former for this most difficult service.

Almost constant trouble was experienced with large spur gears on the locomotives on the Mt. Washington Railway until aluminum bronze was tried. Its service there has proved eminently satisfactory.

Pickle-crate equipment made of aluminum bronze has been found to withstand the action of sulphuric acid well. This fact, combined with its strength, fits it for this purpose. The property of resisting abrasion is useful for gears, but aluminum-bronze trolley wheels have been found to give remarkable service for the same reason. The toughness of the alloy is useful here as well, because the effect of a severe blow can be readily corrected under the hammer without breakage.

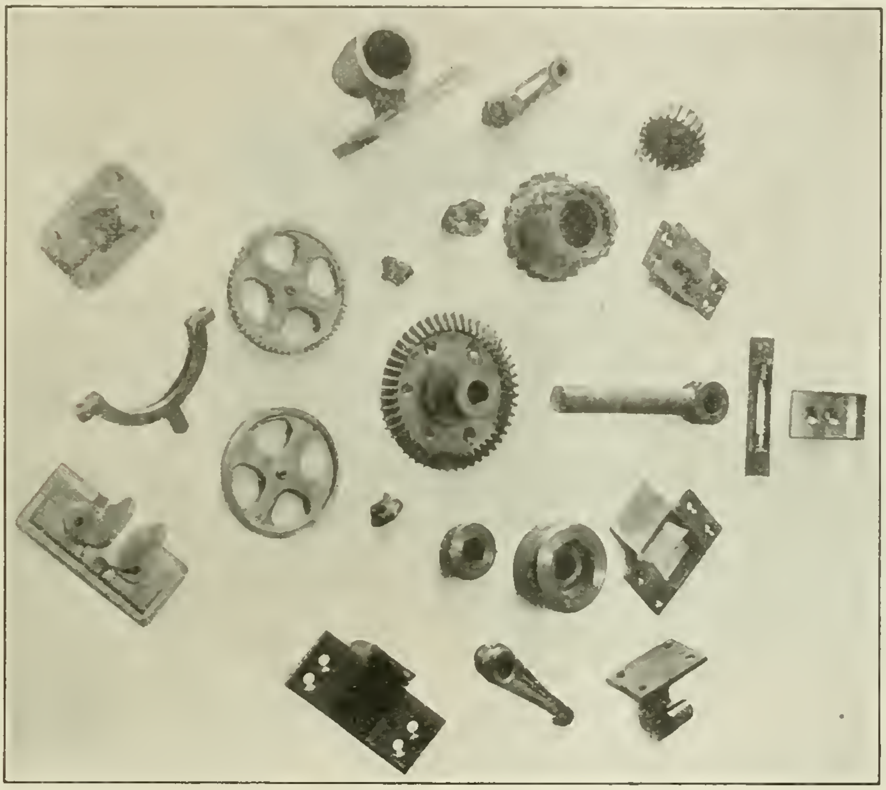

Fig. 1 Intricate Die Castings Made from Aluminum Bronze

Adaptability

Aluminum bronze is tough when cold, but is more so when redhot. This property makes forgings possible and also helps materially in the manufacture of die castings from this metal. A number of intricate die castings are shown in Fig. 1. These are not samples but are taken from regular production runs of lots of 10,000 or more. The process is a commercial one, for the dies are made so that they will withstand at least 10,000 openings in most shapes. The solving of the die problem is of equal importance with the metal problem, for one can not proceed without the other. The property of toughness is useful also in Jordan bars for beating engines. With its freedom from corrosion, the tough aluminum-bronze Jordan bar has been an increasing success in the paper industry.

Machinability

Many excellent properties of aluminum bronze have been mentioned, but it has its drawbacks. First, at least at present, is the difficulty of machining, compared with other bronzes or brasses. This does not mean that it cannot be machined readily under proper conditions, but that, compared to ordinary brass or bronze, its toughness makes it more difficult to handle in the machine shop. Sharp tools, kept so, of the proper angle are essential to success. Ample lubrication is necessary. With these precautions a most excellent job can be done as is evidenced every day at the Ford factory in Detroit. Aluminum bronze most nearly resembles mild steel in its machinability.

When one sees the stacks of golden-bronze worm wheels in the gear department of the Ford Company and examines the polished surface of the gear teeth left after the machining operation, there can be no doubt that aluminum bronze as an engineering material has arrived and that its excellent properties have been made available to the engineer because scientific research solved the problems of its manufacture in the foundry.

[1] Chairman, Division of Research Extension, National Research Council.

[2] Aluminum Bronze Alloys, W. M. Corse, Trans. Am. Inst. Metals, 1915, vol. 9, p. 202.

[3] Aluminum Bronze, Some Recent Tests and Their Significance, Corse and Comstock, Proc. Am. Soc. Testing Materials, 1916, vol. 16, part 2, p. 118.

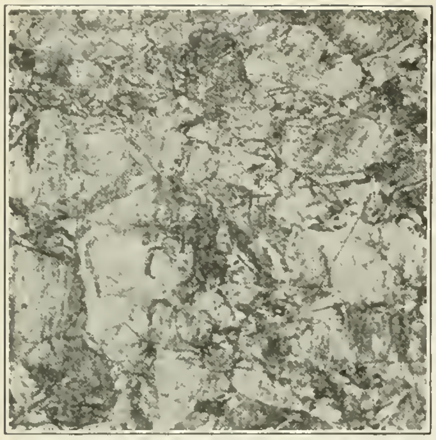

Fig. 2 Hard

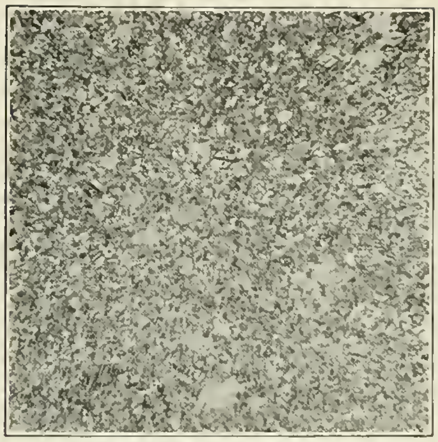

Fig. 3 Light Annealed

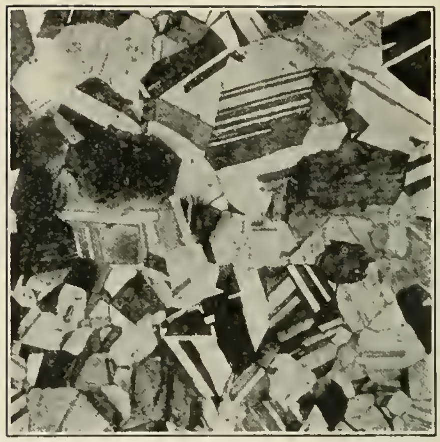

Fig. 4 Soft Annealed

Figs. 2, 3 and 4 Photomicrographs Showing the Structure of 8 Per Cent Aluminum Bronze. Magnification, 75 Diameters
(Percentage composition: Copper, 92.46; iron 0 20; aluminum 7.29.)

The second objection to aluminum bronze might be its cost, which is about 25 per cent more than that of brass or bronze. But when compared to special bronzes with somewhat similar properties the difference in cost disappears.

Like all high-grade metals it must be manufactured under careful supervision, and more than usual care must be used in the casting shop and foundry.

Manufacture

Charles Vickers, in his book, Metals and Their Alloys, just published, devotes a chapter to aluminum bronze and goes into the manufacture and properties of the alloy thoroughly. Vickers devised the flux or degasifier that made the casting of aluminum bronze a commercial success in the sand foundry, and to him we owe much because of his untiring efforts in investigating the complicated problems connected with its manufacture. Vickers patented an alloy of copper, aluminum, and iron which shows markedly improved properties over the alloys without iron. Previously iron was considered detrimental in the manufacture of aluminum bronze, but as a result of Vickers' work many combinations of copper, aluminum, and iron are possible and enable us to make a series of alloys with widely varying properties.

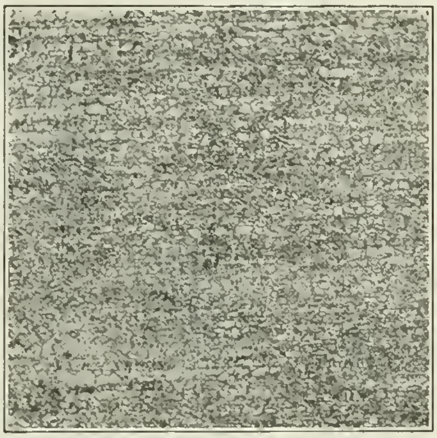

Fig. 5 Structure of Hard 8 Per Cent Aluminum-Bronze Rod. Magnification, 75 Diameters

George F. Comstock has investigated these alloys metallographically and published numerous articles of value on the subject. The author has had the privilege of being associated with the work of both Vickers and Comstock from the beginning, and has assisted in the commercial development of aluminum bronze since 1914. He heartily agrees with the following quotation from Erwin S. Sperry,[1] which, when written in 1905, was a prophecy, but has since become an accomplished fact.

> When a good casting of aluminum bronze is made, it is superior in every way to manganese bronze. I do not say this because I am prejudiced in any way, for I have had fully as much to do with one of these alloys as another; but for the reason that I firmly believe aluminum bronze has met with defeat, not because of its lack of strength, not from its unsuitability for all the work which manganese bronze will do, not on account of its excessive cost, but for the reason that no one has yet mastered its casting so that successful castings may be continuously turned out. When this has been done, and at some future time it will be accomplished, aluminum bronze will replace manganese bronze as it has been replaced itself.

The addition of manganese to the copper-aluminum alloys was investigated by W. Rosenhain and C. A. H. Lantsberry at the National Physical Laboratory, Teddington, England, and described by them in the Ninth Report to the Alloys Research Committee of the Institution of Mechanical Engineers of Great Britain. In general, the addition raises the yield point and tensile strength without diminishing the ductility.

Wrought Aluminum Bronze

Most of the remarks thus far have referred to cast aluminum bronzes, but as rolled or wrought alloys are commercial products and are manufactured in large quantities the author quotes below from W. H. Bassett, whose experience with these alloys gives authority to his statements.

> Aluminum bronze has a high resistance to corrosion, and is used principally when this property coupled with a high tensile strength and hardness is required.
>
> Copper-aluminum alloys can be made in wrought form in any proportions up to an aluminum content of approximately 10 per cent. Three alloys, however, are used principally. These contain 5, 8, and 10 per cent aluminum, respectively. All three alloys hot-roll easily, and these same remarks would apply to the cold rolling of the 5 and 8 per cent. The 10 per cent aluminum bronze does not cold-roll readily, in fact would not be considered a cold working alloy.
>
> The 5 per cent aluminum bronze is furnished principally in the form of sheets. It has when cold-rolled, a tensile strength as high as 100,000 lb. per sq. in., depending upon the degree of hardness or cold rolling, and an elongation in 2 in. of 10 per cent. When annealed this alloy has a tensile strength of 55,000 lb. per sq. in. with an elongation of 75 per cent in 2 in. This high elongation for annealed 5 per cent aluminum bronze is characteristic of the material, and it is rarely equaled in the other non-ferrous alloys.
>
> The 8 per cent aluminum bronze is manufactured extensively in both rod and sheet form, and is supplied when resistance to wear is also required in connection with the other general physical properties given for aluminum bronze.
>
> This alloy is in more general use than any of the other wrought aluminum bronzes. In the form of sheets when cold rolled the tensile strength may be as high as 130,000 lb. per sq. in., with 4 per cent elongation. When annealed this same material has a tensile strength of 60,000 lb. per sq. in. and an elongation of 60 per cent. The generally high tensile strength makes this material very valuable for many engineering purposes.
>
> Micrographs 1, 2 and 3 [Figs. 2, 3 and 4] show, respectively, the structure of 8 per cent aluminum bronze sheets hard or cold-rolled, light annealed, and soft annealed. These particular samples had the following physical properties:

Sample No.	Temper	Tensile strength, lb. per sq. in.	Elongation in 2 in., per cent
1	Cold rolled	102,000	7
2	Light annealed	77,000	36
3	Soft annealed	61,000	62

> Rods in 8 per cent aluminum bronze can also be supplied with approximately the same physical properties as sheet metal. However, it is customary to furnish them in a medium temper with a tensile strength of about 85,000 lb. per sq. in. and an elongation of 30 per cent. Micrograph No. 4 [Fig. 5] shows the structure of a rod of this nature.
>
> The 10 per cent aluminum bronze has, of course, the highest tensile strength and lowest elongation of this series. Owing to the fact that it can be only very slightly cold worked, it does not have the range in physical properties as shown by the other alloys. Its tensile strength may be taken as 75,000 lb. per sq. in. and elongation as 25 per cent. There is not a great demand for this class of material, but when supplied it is usually furnished in the form of hot-rolled sheets, hot-rolled or extruded rods, and extruded

(Continued on page 331)

[1] *Brass World*, vol. 1, p. 400.

Refinery and Rolling Mill for Monel Metal, Huntington, W. Va.

By W. L. WOTHERSPOON,[1] NEW YORK, N. Y.

This paper describes the steps taken in selecting the site for the location of a mill for rolling monel metal. The economic problems involved are stated and the facts leading to their solution are given. The remainder of the paper deals with the layout of the plant, emphasizing certain features of design that are of particular interest.

MONEL metal consists of 67 per cent nickel, 28 per cent copper and 5 per cent other elements, and is a natural alloy. In appearance it resembles nickel and in tensile strength it is comparable with steel, while its resistance to corrosion is very high. Its resistance to acids together with its physical and working qualities (for it can be cut, rolled, welded, machined, and forged) make a combination of properties which are not to be found in other common metals.

Monel metal is produced at the refinery in shot, pig, and ingot from monel-metal bessemer matte consisting of approximately 56 per cent nickel, 24 per cent copper, and 20 per cent sulphur, the iron content being about 0.4 per cent. The mill product consists of forgings, merchant and sheet bars, wire rod in coils, and sheets.

The International Nickel Company, in order to provide facilities for the increased requirements of monel metal, has recently completed a refinery and rolling mill at Huntington, W. Va. The project may be considered as new industry; active development of markets for monel metal having only been undertaken during the last few years, during which requirements have been met by arrangements with various steel mills for production of the above-mentioned products from ingots supplied from the Bayonne, N. J., refinery of The International Nickel Company.

The purpose of this paper is to describe the investigation leading to the location of these works, together with certain features of their design and construction, and to give information on the products manufactured, all of which is believed to be of general interest to engineers and manufacturers.

Investigation Regarding Location for Works

A general survey of requirements in order to prepare preliminary plans, and estimate the costs and acreage necessary, was first made, as a result of which the following conclusions were reached:

a That existing and prospective business for monel metal justified the estimated capital expenditure of approximately $3,000,000 for a rolling mill to produce rods and sheets

b That the potential markets for monel metal and other alloys were such that the plant should be laid out with provision for considerable expansion

c That natural gas, being practically free from sulphur, was the ideal fuel for heating purposes. Should it be necessary to utilize producer gas, the estimated capital expenditure for plant and equipment would be increased approximately by $200,000

d That the particular disposition and service of the merchant and sheet mills was such that individual electric drive, with gear reduction where necessary, would be best

e That purchased electric power was preferable, and if not available capital expenditure would be increased by approximately $750,000

f That at least twenty, and preferably up to fifty, acres were advisable for a site.

With the survey of requirements and the conclusions available, the following districts were given particular study: Bayonne, N. J., Buffalo, N. Y., Baltimore, Md., Pittsburgh, Pa., and Huntington, W. Va.

Although the ores and bessemer matte from which monel metal is produced come from The International Nickel Company's mines and smelter in the Sudbury district of Ontario, Canada, and there had within a few years been constructed by the company a refinery for nickel products at Port Colborne, Ontario, economic factors such as tariff, fuel, markets for finished products, etc., were such as to confine the detailed study of locations for these new works to the eastern half of the United States.

Bayonne, N. J., was considered, as The International Nickel Company's largest refinery had been established there many years and it was thought the rolling mill might be an addition to the existing works. The investigation resulted, however, in the Bayonne refinery being discontinued, the plant dismantled, and one of the most valuable sites on New York Harbor made available for some other industry for which the economic conditions are excellent, but which are unfavorable for the refinery and rolling

Fig. 1 General View of Plant from C. & O. R. R., June, 1922

mill. Important changes and extensions have therefore been made at the Port Colborne refinery so that nickel in all forms can be refined in Canada, and the refinery with rolling mill has been constructed at Huntington, W. Va., for the production of monel metal, malleable nickel, and other specialties.

The following is a list of the economic factors investigated, together with the comparative ratings given them:

Labor	250	Climate	50
Fuels	330	Supplies	60
Power	100	Taxes and laws	20
Living conditions	100	Site (cost and quality)	10
Transportation	50	Construction cost	20
Water supply	10		

The following general conditions apply to the district of Huntington, W. Va., which are considered especially suitable for the industry described:

Labor. Labor is made up of 95 per cent English-speaking Americans, both common and skilled, with good records in the territory in diversified industries; the turnover is light and a majority of the workers own their homes.

Fuels. A plentiful supply of natural gas for manufacturing and domestic purposes, from public-utility companies, is available at a cost of from 18 to 19 cents per 1000 cu. ft. (1100 B.t.u. per cu. ft.). Investigation of developed and undeveloped gas fields indicates supply of gas for 15 to 20 years. A good supply of high-grade oil of low sulphur content is available from the local oil refinery at a present price of 5 to 6 cents per gallon delivered at plant. There is an excellent supply of high-grade bituminous steam and gas coals from local coal fields costing $2.50 to $3.00 per ton, delivered at the plant.

[1] Consulting engineer, International Nickel Co. Mem. A.S.M.E.

Presented at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. Abridged. All papers are subject to revision.

Power. Two modern central stations supply power at a cost to large industries of 11 to 12 mills per kw-hr.

Transportation. Thirteen important railroads make connections within 175 miles. The Ohio River is navigable all the year, traffic between Pittsburgh, Huntington, and Cincinnati being on regular schedule.

Water. Both river and borehole water of good quality are available, the latter at an average depth of 60 ft.

Construction was commenced in 1921 and the plant was placed in operation in June, 1922. Fig. 1 is a general view of works as of June, 1922, and Fig. 2 a plan showing their general arrangement.

Crushing, Grinding, and Calcining Departments

The matte, which is received from the company's smelter in Canada in irregular pieces weighing about 50 lb., is unloaded from box cars and put through a 24-in. by 16-in. jaw crusher, being reduced to about $1^1/_2$-in. product, and is then fed to a No. 8 Krupp-type ball mill to be further reduced by dry grinding to pass a 16-mesh. The crusher and mill capacity is about 45 tons in eight hours, so that with the installation of a large storage bin with seven days' capacity for ground matte, this equipment can be operated intermittently to suit the convenience and arrival of cars of raw material. The crusher, ball mill, and elevators connecting them with each other and with the bin are belt-driven through a line-shaft by a 125-hp. 900-r.p.m. 3-phase high-torque squirrel-cage motor.

The ground matte is then introduced by mechanical feeders to roasting furnaces, of which there are three, the material being handled between the bins and the furnaces by 2-ton-capacity electric traveling monorail trolley hoists.

The roasting furnaces are horizontal, 80 ft. long by 17 ft. wide, and are of a modified Edwards type, the material being moved along the hearth by 32 rabbles operated by mechanical chain and gear transmission and mounted directly over each furnace. These rabbles are of cast iron with monel-metal shoes, and are hollow, being designed especially for efficient water cooling. Natural gas is used as fuel for these furnaces, the capacity of each being about 25,000 lb. per 24 hr., the sulphur in the material being reduced from 20 per cent to 0.005 per cent. The mechanism for each furnace is operated by a 5-hp. 220-volt 900-r.p.m. back-geared motor. The temperature under which roasting is accomplished varies from 2000 deg. fahr. to 500 deg. fahr. The roasted matte is discharged from the furnace by gravity into large buckets, ground charcoal being mixed with the hot material as it is discharged so that its reduction takes place from the time it leaves the roasting furnace.

Large flues with numerous baffles, facilitating the recovery of valuable dust, were given special attention in these furnaces, these connecting with a chimney 200 ft. high and 8 ft. in internal diameter at the top.

Large quantities of charcoal are used, so in this department there is provided as an extension a brick building for the storage of charcoal. Charcoal is procured locally in irregular sticks and, after passing over a conveyor provided with a magnetic pulley to extract any stray metallic substances, is delivered to a gyratory crusher, driven by a 10-hp. 220-volt 900-r.p.m. motor, to be pulverized to about $^1/_2$-in. size. A bin for the storage of crushed charcoal is provided, but the capacity is not large as it is inadvisable, due to the possibility of spontaneous combustion, to store this material in large quantities in ground form.

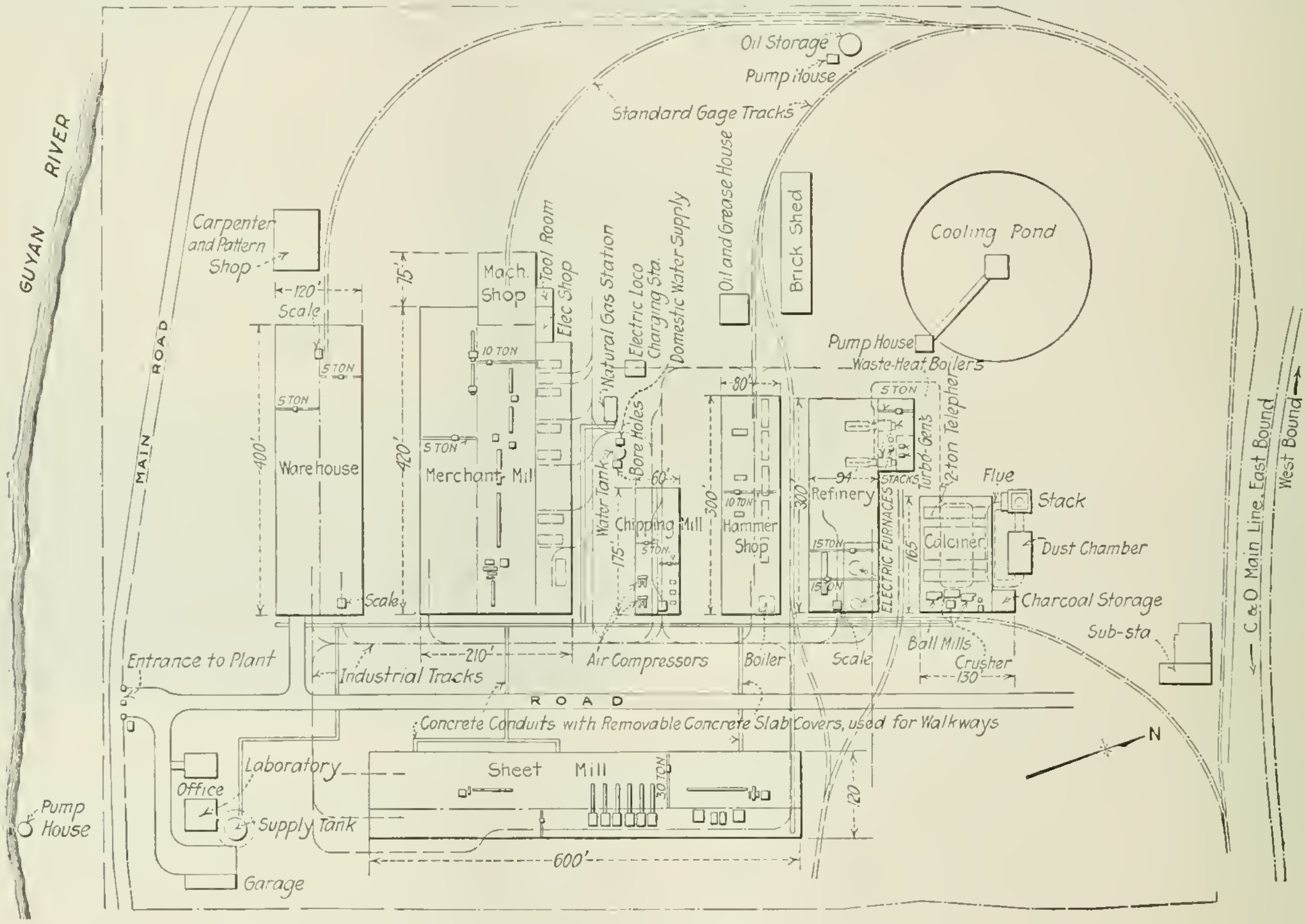

Fig. 2 Plan of Works, Showing General Arrangement

The cooling of the furnace rabbles takes about 100 gal. of water per min., the temperature being raised to 160 deg. fahr., which heat is utilized by pumping the water to the boiler-feedwater storage system of the auxiliary power plant.

The Refinery

The refinery department contains two open-hearth furnaces arranged for firing by either natural gas or oil. The capacity of each furnace approximately 35,000 lb. per day.

The electric traveling monorail-trolley hoist system already referred to operates between the calciner and the refinery departments, delivering the roasted monel-metal oxide from the calciner

furnaces directly to large feed hoppers mounted over the open-hearth furnaces. The telpher also delivers to the same feed hoppers ground charcoal from the crushing and grinding department and amounting to approximately 25 per cent of the furnace charge by weight. The heat utilized in furnaces of this type does not exceed 15 per cent of the value of the fuel, and a 600-hp. boiler of the waste-heat type, with superheater, is connected as close as practicable to each furnace, Fig. 3. The steam generated is used by the steam hammers and in the auxiliary power house.

There are at the side of each open-hearth furnace specially designed tanks used when making monel metal in shot form. This is accomplished by using a movable tapping spout and directing the stream of metal into water. There are also two electric furnaces, one known as the Moore, having a normal capacity of three tons per heat, and the other a Heroult, with a normal capacity of seven tons per heat. The charge floor is 100 ft. by 35 ft., of reinforced-concrete construction. The surface, where subject to rough usage, has an additional reinforcement of Irving grating.

The refinery department is equipped to produce monel-metal ingots directly from the open-hearth furnaces or from the electric furnaces. In the latter practice the furnace charge consists of pig metal produced in the open-hearth furnaces, together with selected scrap. In the work thus far done the power consumption has varied from 642 to 714 kw-hr. per ton of melted monel metal.

The Chipping Department

In order to insure a uniform hammered or rolled product of first-class quality, the outer skin of the monel-metal ingots must first be completely removed. Previous practice has been to remove this outer skin entirely by chipping with pneumatic hammers, a costly and laborious operation.

Experiments on a small scale demonstrated the economic possibilities of milling the surface of the ingots, and three high-powered milling machines belt-driven from a 20-hp. motor were installed in the chipping department. Approximately 250 lb. of metal is milled from the large ingot in an actual cutting time of 2 hr. 40 min. The total time to finish the ingot, including resetting of tools, turning and reclamping of ingots is 4 hr., thirteen operations being required. Eight-inch mills are used of special design with extra heavy steel bodies, case-hardened chip breakers, and ten inserted $1\frac{1}{4}$-in. by $\frac{3}{4}$-in. high-speed-steel blades. The blades are set in the body so that the rake angle which the face of blade makes with a radial line is 15 deg. Cutters of special design are used to mill the corners of the ingots. The face mill is run at 16 r.p.m., taking $\frac{1}{4}$-in. depth of cut with feeds of $4\frac{1}{4}$ in. and $4\frac{5}{8}$ in. per min. Angular cutters are run at 38 r.p.m. with $5\frac{5}{8}$ in. feed per min.

A skilled chipper cannot consistently chip out more than 1200 to 1500 sq. in. per eight-hour shift, or approximately two sides of a two-ton monel-metal ingot, whereas one milling machine finishes an ingot every four hours. This time will be considerably lessened on new machines with improved devices that have been ordered.

After the ingots have been milled they are taken to the chipping benches and carefully inspected. Any small defects that are not entirely eliminated by milling are chipped out by pneumatic chipping hammers. Compressed air for chipping and miscellaneous work is supplied from two direct-connected electrically driven horizontal air compressors located in a corner of the chipping building where most of the air is used. Each compressor will deliver 1030 cu. ft. per min. at 100 lb. gage pressure, and is driven by a 210-b.hp. synchronous motor running at 257 r.p.m.

The Hammer Shop

This department receives the ingots from the chipping shop. The ingots vary in size, depending upon their ultimate use, the major portion being about 13 in. by 13 in. and weighing up to 4 tons. The equipment consists of one 10-ton crane and four steam hammers of 16,000 lb., 10,000 lb., 3500 lb. and 1500 lb. capacity, respectively, together with the necessary handling equipment. There are five heating furnaces of the Stevens regenerative type, four with hearths 7 ft. by 20 ft. and one with a hearth 7 ft. by 14 ft., equipped with manual control and automatic air- and gas-regulating equipment.

Owing to the weight and toughness of monel metal the hammers are of a special design and possess some novel features. The 16,000-lb. and 10,000-lb. hammers are used for cogging or breaking down. These hammers are of a special double-frame type and are built of steel throughout. The main cylinders are bushed and valves of a new design assuring economy of steam and at the same time allowing for full control by the operator, have been embodied in their construction. The weight of one frame of the 16,000-lb. hammer is 44,000 lb., and the total weight, including the anvil, is 370,000 lb. The frames are held together at the bottom by a massive cast-steel base plate, giving a rigid construction. The ratio of the anvil weight to the falling weight is 15 to 1. Cushioned

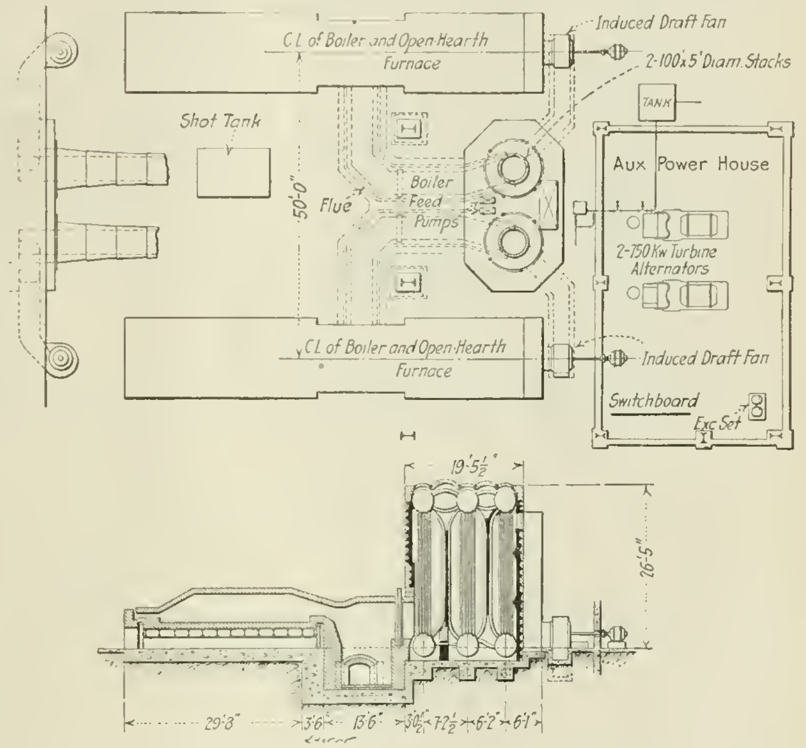

Fig. 3 Plan and Elevation Showing Arrangement of Open-Hearth Furnaces with Waste-Heat Boilers and Auxiliary Power Plant

safety cylinder covers are used with these hammers, also special guides and shoes.

The two smaller hammers follow the same general lines except they are of the two-leg type and in some parts cast iron replaces steel. Special shapes are forged on these hammers, in addition to the usual forged work.

The Rolling Mills

The mills consist of two departments:

a Merchant and wire-rod mills for the production of sheet bars, billets, rods of various sizes and shapes, and wire rod in coils

b A sheet mill for the production of hot- and cold-rolled sheets.

On account of the extremely tough character of monel metal and the tendency it has of cooling rapidly, it is necessary to have mills of great strength and rigidity. The type of material rolled is similar to alloy tool steel and it is very necessary to have mills with machine work and general finish the best of its kind and that are equipped with fittings that require a minimum of adjustment.

The hammered ingot or bloom after being overhauled to remove any scale or surface imperfections is delivered to the 24-in. sheet-bar mill, located in the merchant-mill building, Fig. 4. This mill consists of two stands, the first stand three-high and the bull head, or finishing stand, two-high.

The handling of blooms to the heating furnaces and thence to the standard mill tables is by means of a Brosius charger. The tilt-

ing tables, 25 ft. long, the transfer, and other table operations are controlled from the same pulpit. After being rolled the bar is carried to an exceptionally heavy shear with a capacity to cut $3\frac{1}{2}$-in. by 12-in. billets.

The Sheet Mills

The general arrangement of the sheet mills is shown in Fig. 5. The mills themselves are exceptionally heavy, the roll diameters

by a motor drive, a 40-hp. motor being used which is carried on the top of the pinion housing. The main motor to drive this mill is a 1200-hp. motor, which is geared with a double-reduction gear giving a total reduction of 13 to 1 and a mill speed of 26 r.p.m. Two 10-ton flywheels are used, running at the motor speed approximately 10,000 ft. per min.

The furnaces are of the wide-door type, being double sheet furnaces and four-door pair furnaces. The air at 16 oz. is furnished

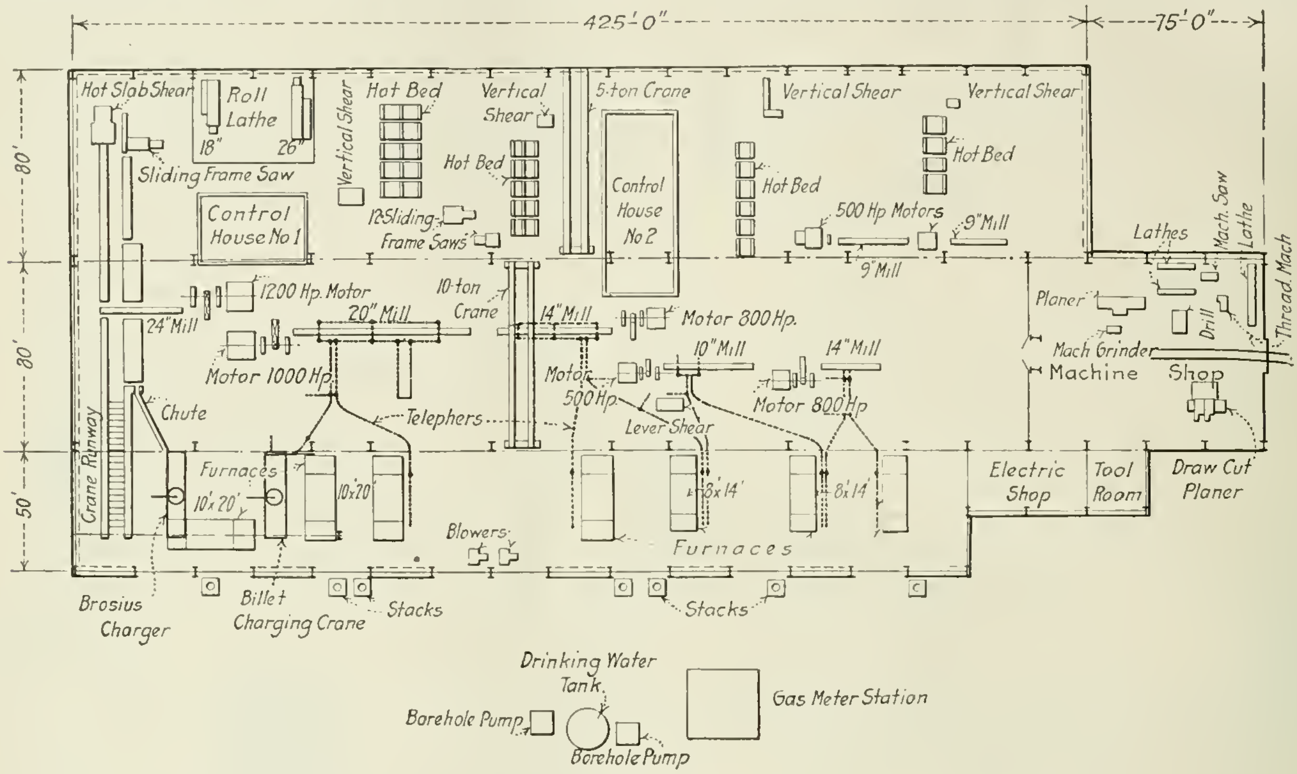

Fig. 4 General Plan of Merchant Mill

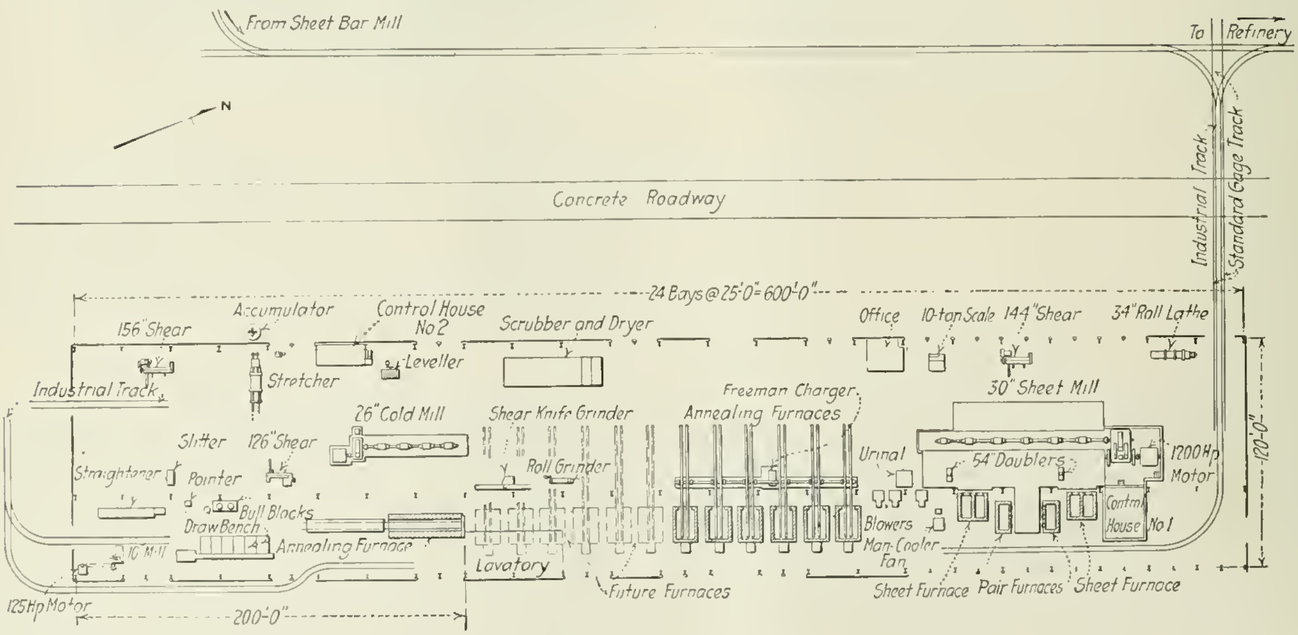

Fig. 5 General Plan of Sheet Mill

being 30 in. and the maximum sheet width 48 in. The present complement consists of two finishing mills and two roughing mills, each finishing mill having a roughing mill of its own. The roughing rolls are balanced and are driven by fully enclosed cut gears, a rather new development in sheet-mill practice, giving a very smooth movement and reducing the tendency of the pinion teeth to mark the sheet. A specially designed drag, known as the "Conklin" drag, is furnished. The roughing rolls are screwed up and down

by three blowers, of 4000 cu. ft. per min. capacity, which also furnish the air for the six annealing furnaces. Natural gas is used in all furnaces. The annealing furnaces are equipped with Freeman-type charging machines. The crane capacity over this mill is 30 tons with a 25 per cent overload and a 10-ton auxiliary.

The 26-in. cold-roll mill at the south end of the building consists of four stands of cold rolls driven by a 300-hp. motor. Construction

(Continued on page 331)

High-Temperature and High-Pressure Steam Lines

By B. N. Broido,[1] New York, N. Y.

The pronounced tendency of modern power-plant designers to use high superheat and high pressure, as well as the recent extensive use of highly superheated steam in process work, lead the author to make a review of the available data and formulas on radiation and friction losses in pipe lines. All tests to determine the radiation losses of pipe lines carrying high-temperature steam made in this country have been practically exclusively with electrically heated pipes. This paper gives results and an analysis of tests made with superheated steam flowing through a pipe line. The heat-transmission coefficients of bare and covered pipes at various steam velocities, superheats, and pressures are given. Suggestions are made regarding the steam velocities to be selected in order to transmit steam more economically.

The formulas available at present for figuring the friction losses of steam in pipe lines are limited to the range for which they were established, or for comparatively low pressures. Corrections of these formulas are shown in this paper, based on observations of a pipe line carrying high-pressure steam, which corrections may be used by designers of high-pressure power plants in dimensioning their pipe mains.

The paper further treats of pipe lines carrying superheated steam for other purposes than power. Recommendations as to the velocities or pipe sizes to be chosen are given, as well as a few examples from practice to show how the velocities selected were advantageously applied.

The use of superheated steam in power plants, as well as for various kinds of process work, has become so extensive during recent years that it is hardly necessary to enlarge on its advantages. The fuel saving effected by the use of superheated steam, the lower maintenance cost of turbines using it, and the numerous advantages it has in various kinds of process work are some of the factors which have helped to assign to it the important position it now occupies in the opinion of technical men.

One of the phases in which engineers, power-plant operators, and managers are naturally interested in this connection is that of conducting superheated steam through pipe lines. Very little, however, has been published in this country on the subject.

The recent tendency in designing power plants, particularly those of large size, is toward high pressures. The high temperatures and high pressures involve new problems, among others being that of proportioning the pipe lines. A study of the losses of heat and pressure in pipe lines carrying highly superheated and high-pressure steam at the present opportune time will aid the designer in dimensioning the steam lines.

The field is very large, and this paper will therefore be confined to the discussion of—

a Radiation losses in pipe lines carrying superheated steam
b Resistance to the flow or pressure drop of superheated steam in pipe lines
c The most advantageous steam velocity, particularly for high-pressure lines; and
d Other features to be taken in consideration in designing pipe lines for transmission of superheated steam of either low or high pressures.

Radiation Losses in Pipe Lines Carrying Superheated Steam

Up to the present the usual method of determining radiation losses has consisted in supplying saturated steam to a pipe either naked or covered with a definite thickness of lagging, and weighing the amount of steam condensed. Such experiments, however, are mostly inaccurate, due to the fact that no separator completely removes the moisture from the steam, and also because of the difficulties in completely draining the tested pipe. So far as the author is aware, no experiments with superheated steam in pipe lines have been made in this country.

The author has had the opportunity to study this subject and to examine the results of tests conducted in Europe in which both saturated and superheated steam were used, particularly the tests made by Dr. Bernard and Herr Eberle of Magdeburg and Munich, respectively.[1] Table 1 shows the results of tests with saturated steam in bare pipes of approximately 3 in. and 6 in. internal diameter. The surfaces given in the table include the surface of the flanges. It is of interest to note that while the temperature of the pipe wall was very near to that of the steam, the temperature of the flanges was slightly lower. The difference in some cases is as high as 30 deg. fahr.

The tests were also conducted with different types of insulation, the results, however, being similar to those obtained in like tests in this country.

Tests to determine the heat loss by transmission of superheated steam can be carried out only with steam that is flowing. The heat content of steam, both at the inlet and outlet of the pipe, must be determined, and the difference multiplied by the amount of steam flowing through the pipe gives the heat loss. Superheated steam flowing through a pipe may change its heat content—

a By decreasing its temperature
b By pressure drop
c By partial condensation.

The accurate measurement of any condensed water would be impossible, due to the fact already mentioned that separators are not reliable. To be accurate, tests with superheated steam must therefore be conducted with sufficiently high temperatures so that the temperature of the pipe wall at the outlet does not descend below that of saturated steam at the same pressure.

TABLE 1 HEAT LOSS FROM 3-IN. AND 6-IN. BARE PIPES—SATURATED STEAM

Pipe Line: Length, ft.	Pipe Line: Inside diam., in.	Pipe Line: No. Flanges	Pressure abs., lb. per sq. in	Steam temp., deg. fahr.	Air temp., deg. fahr.	Temp. diff. betw. steam air, deg. fahr.	Condensed water for 1 ft. length, lb. per hr.	Heat Loss: Per sq. ft. surface per hr., B.t.u.	Heat Loss: Per sq. ft. per deg. temp. diff. per hr., B.t.u.
			46.60	274.46	60.98	213.48	0.5174	575.7	2.672
			46.01	273.56	59.54	214.02	0.5168	575.3	2.672
			46.45	274.10	61.88	212.22	0.5114	570.2	2.672
			96.43	322.52	65.66	256.86	0.6948	744.0	2.876
87.25	2.76	6	96.87	322.88	62.96	259.92	0.7063	755.9	2.876
			95.84	322.16	70.34	251.82	0.6982	758.5	2.958
			190.22	374.72	76.10	298.62	0.9092	932.4	3.100
			191.69	375.26	71.06	304.20	0.9415	964.7	3.142
			47.78	275.9	72.50	203.40	1.0362	545.4	2.672
			48.95	277.34	78.26	199.08	1.0087	537.2	2.652
			99.23	324.68	89.06	235.62	1.3628	689.3	2.897
85.28	5.91	7	98.78	324.32	86.36	237.96	1.3803	698.9	2.917
			192.13	375.44	87.08	288.36	1.9320	935.7	3.223
			191.98	375.44	95.75	279.69	1.8715	906.9	3.223

Knowledge of the wall temperature was considered important, not only to determine the minimum superheat required to eliminate condensation, but also to determine the coefficient of heat transfer from superheated steam to a pipe wall.

In view of the fact that the velocity of superheated steam doubtless has an influence upon the heat transmission, tests were conducted with different velocities. The results of tests conducted with bare pipes were highly impressive. At a velocity of about 100 ft. per sec. and steam temperatures of 291 to 390 deg. cent. (556 to 734 deg. fahr., corresponding to 221 and 399 deg. super-

[1] Consulting engineer, The Superheater Company. Mem. A.S.M.E.

Contributed by the Power Division and presented at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. Abridged. All papers are subject to revision.

[1] Mitteilungen über Forschungsarbeiten (Berlin), V. D. I., Hefte 21 and 78.

TABLE 2 COEFFICIENTS OF HEAT-TRANSMISSION FOR BARE AND COVERED PIPES AT VARIOUS STEAM TEMPERATURES AND SAVINGS RESULTING FROM COVERING PIPE—SUPERHEATED STEAM

Final steam temp., deg. fahr.	3-in. Line			6-in. Line		
	K		Saving through covering, per cent	K		Saving through covering, per cent
	Bare pipe, B.t.u.	Covered pipe, B.t.u.		Bare pipe, B.t.u.	Covered pipe, B.t.u.	
212	2.4	0.47	80.4	2.32	0.381	83.6
230	2.48	0.47	81.1	2.42	0.383	84.2
248	2.57	0.47	81.7	2.52	0.385	84.7
266	2.64	0.47	82.3	2.62	0.387	85.3
384	2.73	0.47	82.8	2.72	0.389	85.7
302	2.81	0.47	83.4	2.81	0.391	86.1
320	2.89	0.47	83.8	2.91	0.393	86.5
338	2.98	0.47	84.2	3.01	0.395	86.9
356	3.06	0.47	84.6	3.1	0.397	87.2
374	3.14	0.47	85.0	3.2	0.399	87.5
392	3.22	0.47	85.4	3.3	0.401	87.9

TABLE 3 VARIATION OF HEAT LOSSES, HEAT-TRANSMISSION COEFFICIENTS FOR BARE AND COVERED PIPES AND SAVINGS RESULTING FROM COVERING PIPE, WITH TEMPERATURE DIFFERENCE BETWEEN STEAM AND AIR —SUPERHEATED STEAM

Temperature difference between steam and air, deg. fahr.	Heat loss per square foot of outside pipe surface per hour		Saving through the covering, per cent	K	
	Bare pipe, B.t.u.	Covered pipe, B.t.u.		Bare pipe, B.t.u.	Covered pipe, B.t.u.
212	453	78.5	82.7	2.50	0.43
257	606	103.2	83.0	2.67	0.45
302	773	130.2	83.2	2.83	0.48
347	971	160.5	83.5	3.06	0.51
392	1184	192.4	83.7	3.26	0.53
437	1394	225.2	83.8	3.43	0.55
482	1637	260.8	84.1	3.63	0.57
527	1909	303.4	84.1	3.83	0.60
572	2192	344.1	84.3	4.04	0.63
617	2497	384.8	84.6	4.22	0.65
662	2804	429.2	84.7	4.43	0.67
707	3135	478.7	84.7	4.61	0.70
752	3149	529.8	81.8	4.81	0.73

heat), the temperature difference between the steam and pipe wall was 34 deg. cent., while α_1 the heat-transmission coefficient was 35. With steam velocities of 33 ft. per sec. the difference between the steam and the pipe-wall temperatures was greater. At the lower steam temperatures of 220 to 267 deg. cent. (428 to 513 deg. fahr.) the temperature difference was 45 to 65 deg. cent. (86 to 122 deg. fahr.) and the heat-transmission coefficient α_1 was 16. By decreasing the velocity of the steam one-third, the coefficient of heat transmission between superheated steam and the pipe wall was decreased to one-half of the first value. This indicates clearly that the behavior of superheated steam is different from that of saturated steam as far as imparting heat to a metallic wall is concerned, which is due to the fact that saturated steam, in transferring heat to the pipe wall, partly condenses or gives up some of its latent heat, which heat is not as closely combined with the steam as the sensible heat of a liquid or the heat of superheat. This fact often is not understood, even by technical men.

While the results of the tests with bare pipe—particularly the variation of the heat-transmission coefficient at different temperatures and velocities—are not important in connection with pipe lines which invariably are insulated, they are of considerable interest as far as the use of superheated steam for heating and drying purposes is concerned.

The experiments demonstrate that the heat-transmission coefficient increases considerably with the increased velocity, and also that the wall temperature depends not only upon the steam temperature but also upon its velocity.

Table 3 gives the results obtained with superheated steam in covered pipes. The same covering was used as for the test with saturated steam. A comparison of the values of Tables 2 and 3 for saturated and superheated steam in covered pipes brings out the fact that for the steam-temperature range from 100 to 200 deg. cent. (212 to 392 deg. fahr.), with either saturated or superheated steam, the heat-transmission coefficient K remains practically the same. With increased temperatures this coefficient shows a tendency to rise considerably. For temperatures from 100 to 200 deg. cent. (212 to 392 deg. fahr.), K for lines with pipes and flanges covered is about 0.47. It increases, however, with the steam temperature, up to 0.69 at 400 deg. cent. (752 deg. fahr.).

While from the tests one would conclude that the direct radiation losses for superheated steam are not appreciably lower than those of saturated steam of the same temperature, there are, however, a few other points to be considered in estimating the relative advantages of the two so far as their transmission through pipe lines is concerned. With saturated steam any heat radiated causes a part of the steam to be condensed, and the condensate, particularly for long pipe lines, is not returned to the boiler but is discharged through traps and wasted, so that in addition to the direct heat lost by radiation there is a further loss of the liquid heat of the condensate, which in some cases, particularly for high-pressure steam, may amount to 25 per cent of the radiated heat. With superheated steam the heat lost only decreases the temperature and no condensation occurs as long as the steam remains superheated so that no additional heat besides that radiated is wasted.

Another important fact to be considered in connection with superheated steam is that a considerably higher velocity in the pipe lines is permissible. The velocity of the steam in a pipe, or the size of the pipe, is usually determined by the maximum friction loss or pressure drop which can be allowed.

Due to the low pressure drop and high velocity possible with superheated steam a greater amount of steam can be transmitted with the same pipe, so that the radiation losses per unit weight are less. Therefore, in order to make a fair comparison between the radiation losses in carrying superheated and saturated steam, not the direct heat should be considered, but the total heat losses in percentage of the heat conveyed in the steam through the pipe. Table 4 gives the heat losses in pipe lines from 4 to 12 in. in diameter for saturated steam and for steam superheated 100, 150, and 200 deg., at gage pressures of 100, 150, and 200 lb. The values are calculated using the heat-transmission coefficients as given in Tables 2 and 3, and the values for saturated steam include the liquid heat of the condensed steam.

Pressure Drop of Superheated Steam in Pipe Lines

The question of friction loss in pipe lines carrying gases or vapors has been studied by many authorities, and a number of formulas have been established which differ considerably. The author has had the opportunity of making observations on the friction loss in long pipes with both superheated and saturated steam, and after a considerable study of the subject, has come to the conclusion that, particularly for long pipe lines and moderate pressures, the formula—

$$P = \frac{CW^2L\left(1 + \frac{3.6}{d}\right)}{Vd^5}$$

which varies with the diameter of the pipe—using the coefficient 0.0001321 suggested by Babcock—is approximately correct for smaller pipe lines up to 4 in. in diameter; while for larger pipes, especially with wet steam, the formula $P = CW^2L/Vd^5$, with the coefficient suggested by Martin, Hawksley or Gutermuth, varying from 0.0003135 to 0.0003557 and depending upon the wetness of the steam and the surface of the pipe, is more likely to be correct.

For superheated steam with low temperatures and low velocities so that the wall temperature is lower than that of saturated steam and the walls are therefore covered inside with a film of water, the pressure drop is approximately the same as that of dry saturated

steam. With higher temperatures, higher velocities and correspondingly higher wall temperatures so that the pipe remains dry inside, the coefficient C for superheated steam varies not only with the diameter of the pipe but also with the velocity, the pressure, the absolute temperature, and the density; and the friction loss agrees closely with that observed by Fritsche,[1] so that his suggested

where—

T = absolute temperature, deg. fahr.
p = absolute pressure, lb. per sq. in.
w = velocity, ft. per sec.
d = pipe diameter, ft.
R = 85.7 for steam.

TABLE 4 COMPARISON OF CAPACITY, RADIATION LOSS AND PRESSURE DROP OF PIPE LINES TRANSMITTING SATURATED AND SUPERHEATED STEAM

Saturated Steam								Superheated Steam								
Press. abs., lb. per sq. in.	Press. drop, lb. per sq. in.	Velocity ft. per min.	Wt. of steam, lb. per hr.	Million B.t.u. trans. per hr.	Rad. loss	Total loss	Per Cent loss	Press. abs., lb. per sq. in.	Deg. super-heat	Press. drop, lb. per sq. in.	Velocity, ft. per min.	Wt. of steam, lb. per hr.	Million B.t.u. trans. per hr.	Rad. loss	Per cent loss	Per cent saving
4-In. Pipe (Extra Strong Above 125 Lb. Pressure)																
									100	1.24	6,000	7,020	7.46	26,400	0.34	27.7
115	0.54	3000	4,080	4.12	16,060	19,400	0.47	115	150	1.18	6,000	6,575	7.15	28,800	0.40	14.9
									200	1.12	6,000	6,225	6.92	33,200	0.48	......
									100	1.75	6,000	8,975	9.65	26,850	0.28	33.3
165	0.79	3000	5,170	5.25	17,650	22,180	0.42	165	150	1.67	6,000	8,400	9.22	31,200	0.34	19.01
									200	1.58	6,000	7,910	8.90	35,800	0.40	4.76
									100	2.17	6,000	11,480	12.40	28,800	0.23	37.9
215	1.03	3000	6,560	6.67	18,900	24,375	0.37	215	150	2.04	6,000	10,750	11.78	33,400	0.28	24.3
									200	1.91	6,000	10,135	11.20	38,600	0.34	8.1
6-In. Pipe (Extra Strong Above 125 Lb. Pressure)																
									100	0.75	6,000	16,000	17.66	37,400	0.21	27.6
115	0.36	3000	9,660	9.75	23,650	28,780	0.29	115	150	0.71	6,000	15,550	16.92	42,450	0.25	13.8
									200	0.67	6,000	14,710	16.35	49,000	0.30	......
									100	1.04	6,000	20,280	21.80	39,400	0.18	40.0
165	0.55	3000	10,520	10.78	26,000	32,670	0.30	165	150	0.99	6,000	19,000	20.85	46,000	0.22	26.7
									200	0.94	6,000	17,900	20.15	52,650	0.26	13.3
									100	1.29	6,000	25,950	28.00	42,400	0.15	42.35
215	0.72	3000	13,500	13.75	27,900	36,000	0.26	215	150	1.22	6,000	24,320	26.85	48,900	0.18	30.8
									200	1.16	6,000	22,950	25.90	56,700	0.22	15.4
8-In. Pipe (Extra Strong Above 125 Lb. Pressure)																
									100	0.71	7,000	32,410	34.5	48,600	0.14	33.3
115	0.37	3500	18,820	19.0	31,800	39,500	0.21	115	150	0.67	7,000	30,390	33.1	55,100	0.17	19.05
									200	0.64	7,000	28,710	31.85	63,700	0.20	4.76
									100	0.99	7,000	41,470	44.45	51,380	0.12	29.4
165	0.54	3500	24,200	24.55	33,900	42,600	0.17	165	150	0.94	7,000	38,810	42.6	59,770	0.14	15.62
									200	0.89	7,000	36,580	41.08	68,610	0.17	......
									100	1.23	7,000	53,040	57.23	55,130	0.10	33.3
215	0.70	3500	31,150	31.7	36,300	46,800	0.15	215	150	1.16	7,000	49,680	54.90	63,740	0.12	20.0
									200	1.10	7,000	46,880	52.97	73,980	0.14	6.67
10-In. Pipe (Extra Strong Above 125 Lb. Pressure)																
									100	0.69	8,000	58,200	61.87	60,760	0.10	28.5
115	0.38	4000	33,850	34.15	38,410	46,750	0.14	115	150	0.65	8,000	54,500	59.30	68,900	0.12	14.25
									200	0.63	8,000	51,500	57.16	79,530	0.14	......
									100	0.95	8,000	77,500	83.10	63,670	0.08	33.3
165	0.56	4000	45,200	45.88	42,280	53,130	0.12	165	150	0.91	8,000	72,500	79.60	74,580	0.09	25.0
									200	0.86	8,000	68,400	76.80	85,620	0.10	6.65
									100	1.19	8,000	99,100	106.9	68,800	0.06	40.0
215	0.72	4000	58,200	59.30	45,320	58,460	0.10	215	150	1.13	8,000	92,800	102.5	79,530	0.08	20.0
									200	1.07	8,000	87,600	98.9	92,320	0.09	10.0
12-In. Pipe (Extra Strong Above 125 Lb. Pressure)																
									100	0.87	10,000	104,200	110.8	72,070	0.07	22.3
115	0.50	5000	60,720	61.27	45,570	55,470	0.09	115	150	0.82	10,000	97,800	106.4	81,600	0.08	11.12
									200	0.78	10,000	92,500	101.8	94,340	0.09	......
									100	1.18	10,000	140,900	151.0	76,050	0.05	37.5
165	0.72	5000	82,170	83.4	50,100	62,950	0.08	165	150	1.11	10,000	131,900	144.8	88,470	0.06	25.0
									200	1.06	10,000	124,100	139.1	101,560	0.07	12.5
									100	1.45	10,000	180,100	191.3	81,600	0.04	42.8
215	0.93	5000	105,800	107.8	53,650	69,220	0.07	215	150	1.38	10,000	168,950	186.7	94,340	0.05	28.6
									200	1.32	10,000	159,150	179.8	109,500	0.06	14.29

formula for the coefficient C which follows can be considered reliable and used safely in calculating the pressure drop for long pipe lines carrying superheated steam and moderate pressures:

$$C = 0.0000022\ (R/144)^{0.148}\ (T/pw)^{0.148} d^{-0.269}$$

In order to facilitate the use of this formula a table was calculated giving for air (R = 53.34) the values of 1,000,000 C corresponding to values of the ratio T/pw for pipe diameters ranging from 1 in. to 48 in. This table is given in Marks' Mechanical Engineers' Handbook. When used for steam its values must be increased by 7 per cent on account of the different value of R used.

[1] Mitteilungen über Forschungsarbeiten, V. D. I. (Berlin), Heft 60.

As far as the author knows, all formulas for determining pressure drop, particularly for steam, are based on tests where the pressures in no case exceeded 300 lb. per sq. in. For higher pressures they should be used with caution. In his extensive study of this subject and search for a formula which would cover all conditions, Biel[1] found that the pressure drop caused by the resistance to flow of any fluid, for the same diameter of pipe, the same length, the same temperature, and the same constant R, can be expressed by the equation $P_d = CW^n p^m$, in which the values of the exponents are $n = 1.852$, $m = 0.852$. Approximately the same values were found by Brabbée,[2] who made extensive tests, particularly to determine the resistance, in pipe lines, for high- and low-pressure steam and hot-air heating. He found, however, that the exponents vary with the roughness of the pipe. For steel pipe his exponent is 0.853.

The question arises as to how far the known formulas for the resistance of flow are applicable to high-pressure and high-temperature steam. It is the opinion of the author that the pressure drop in *straight lines* carrying superheated steam of 300 to 600 lb. pressure is from 10 per cent to 25 per cent less than that calculated by the use of the existing formulas for moderate pressures.

A comparison of the results of tests made at pressures between 250 and 440 lb. with those obtained by using the Fritsche formula bears out this statement. The pressure drop in fittings and bends was carefully determined by mercury U-tubes, and the resistance to the flow, which is usually expressed in lengths of straight pipe, was considerably higher than formerly supposed. As compared with the formula of Conrad Meier, given in the paper of D. E. Foster,[3] the values obtained were from 20 per cent to 35 per cent higher.

The foregoing would tend to show that most of the pressure drop in pipe lines takes place in the bends, fittings, and valves, especially the latter, rather than in the straight pipes. In particular, sudden restriction of area and change in direction of flow affect the pressure of the steam. This has been verified by careful tests even with moderate pressures.

Best Velocity of Steam Flow for Use in High-Pressure Lines

It is therefore apparent that in pipe lines carrying high-pressure steam, provided they consist of long, straight pipe sections, high velocities are permissible, and for high pressures—say, from 300 to 500 lb.—10,000 to 12,000 ft. per min. seems to be the most advisable for lines over 5 in. in diameter and with a continuous steam flow, as, for instance, when the steam is used in turbines. With reciprocating engines, naturally, lower velocities are to be chosen, depending upon the length of the line, the percentage of cut-off, and the number of revolutions of the engine. For high-pressure reciprocating engines located at a considerable distance from the steam generator it was found advisable to make that portion of the steam line near the engine of a larger diameter in order to minimize the fluctuation of the steam flow due to the intermittent steam demands of the engine, and to allow higher velocities by means of a correspondingly smaller pipe diameter, near the boiler.

If a line carrying high-pressure steam contains a number of bends, fittings, and valves, lower velocities than those mentioned in the preceding paragraph should be employed if excessive pressure drop is to be avoided.

The higher cost of the larger sizes necessitated by lower velocities, and the strength of the material required for higher pressures, are factors to be taken in consideration in determining the size of the line.

The table previously mentioned giving values of 1,000,000 C is intended only for low pressures. Table 5 has therefore been devised to give values of the same quantity for pressures up to 600 lb. and any superheat. Table 6 gives the pressure drop and radiation losses for pipes from 8 to 12 in. in diameter and for 300 to 400 lb. pressure.

TABLE 5 VALUES OF 1,000,000 C

Diameter in inches	Values of the ratio T/Pw						
	0.008	0.01	0.015	0.02	0.03	0.04	0.05
4	1.35	1.38	1.43	1.46	1.53	1.60	1.65
5	1.23	1.29	1.33	1.37	1.44	1.50	1.55
6	1.16	1.21	1.26	1.30	1.37	1.43	1.48
8	1.10	1.14	1.18	1.22	1.27	1.33	1.37
10	1.03	1.07	1.11	1.14	1.19	1.25	1.29
12	1.00	1.03	1.07	1.10	1.14	1.19	1.23

TABLE 6 PRESSURE DROP AND RADIATION LOSSES IN PIPE LINES CARRYING HIGH-PRESSURE SUPERHEATED STEAM

Pressure Abs. lb.	Deg. Super Heat	Pressure Drop	Velocity ft. per min.	Wt. Steam lb. per hr.	Million B.t.u. trans per hr.	Rad. loss	Pressure abs. lb.	Deg. Super heat	Pressure drop	Velocity ft. per min.	Wt. Steam lb. per hr.	Million B.t.u. trans per hr.	Rad. loss
4-in. Pipe (Extra Strong)													
315	100	2.60	6000	16450	17.92	32100	415	100	3.03	6000	21190	23.25	34750
315	150	2.46	6000	15400	17.18	37150	415	150	2.84	6000	19740	22.20	39550
315	200	2.34	6000	14470	16.50	42200	415	200	2.68	6000	18460	21.20	45250
6-in. Pipe (Extra Strong)													
315	100	1.58	6000	37300	40.60	47300	415	100	1.79	6000	47900	52.60	51350
315	150	1.48	6000	34900	38.90	54750	415	150	1.68	6000	44600	50.20	58400
315	200	1.39	6000	32700	37.40	62000	415	200	1.59	6000	41750	48.00	66900
8-in. Pipe (Extra Strong)													
315	100	1.44	7000	76000	82.80	60600	415	100	1.68	7000	97900	107.3	65750
315	150	1.36	7000	71200	79.50	70200	415	150	1.57	7000	91250	102.6	75000
315	200	1.29	7000	66900	76.40	79700	415	200	1.49	7000	85400	98.2	86000
10-in. Pipe (Extra Strong)													
315	100	1.37	8000	142100	154.8	76800	415	100	1.57	8000	183000	205.0	83250
315	150	1.29	8000	133000	148.2	88700	415	150	1.48	8000	170400	192.0	94900
315	200	1.22	8000	125000	142.7	100900	415	200	1.4	8000	159500	183.6	108700
12-in. Pipe (Extra Strong)													
315	100	1.65	10000	258500	282.0	91300	415	100	2.04	10000	332500	365.0	99000
315	150	1.56	10000	242000	270.0	105200	415	150	1.90	10000	309500	348.0	112700
315	200	1.47	10000	227000	259.0	119800	415	200	1.79	10000	290000	334.0	129200

Pipe Lines Carrying Superheated Steam for Other Purposes Than Power Generation

The question of friction losses or pressure drop in a pipe line, particularly with superheated steam, is of importance only when the steam is used for generation of power. If it is used for heating, drying, or process work, only its temperature need be considered, the pressure being of no consequence. Higher velocities can therefore be chosen. Very often the pressure has to be reduced before the steam be used, and a pressure drop in the pipe line is even desirable. With saturated steam, however, it is necessary to limit the velocity. The usual velocities with saturated steam in commercial pipe lines are about 3000 to 6000 ft. per min. Any considerably higher velocity increases the danger of water hammer, particularly in long lines with a number of bends, fittings, and changes in diameter, and when the line cannot be completely and continuously drained. In such lines high velocities with saturated steam cause considerable vibration, especially when *much* moisture is carried with the steam, due to the effect at higher velocities of the greater weight of water at any change in direction of the flow.

With superheated steam, particularly at sufficiently high temperatures, practically no moisture is present in the line, and nothing prevents the use of the highest speeds desired. Velocities of

[1] Mitteilungen über Forschungsarbeiten, Heft 44.
[2] Zeitschrift des Vereines deutscher Ingenieure, 1916.
[3] Effect of Fittings on Flow of Fluids through Pipe Lines, Trans. A.S.M.E., vol. 42, p. 647.

12,000 to 15,000 (and more) ft. per min. can be and have been applied in larger pipe lines without any undesirable effects. In figuring the total radiation losses in Table 4, velocities of 3000 to 5000 ft. per min. were assumed for saturated steam, and 6000 to 10,000 ft. for superheated steam, which are conservative values that enable a fair comparison to be made.

Table 4 shows that the greatest saving, as far as radiation losses are concerned, is obtained with 150 deg. superheat, so that when the steam is superheated only for the purpose of elimination of condensation or reduction of radiation, a moderate superheat of 100 to 150 deg., depending upon the length of the line, is sufficient. It does not mean, however, that moderate superheat is in general more desirable. If the steam is used for power purposes, the advantages of high superheat in the prime mover will more than overbalance the slightly higher radiation losses.

A remarkable feature is the very slight increase of pressure drop, which throughout the whole range of the table, with one exception, does not exceed 1 lb. for 100 ft. of pipe length, in spite of the fact that the velocity was doubled. The lower density of superheated steam, the absence of mositure, the dry pipe walls, and the reduced amount of foreign matter—the greatest part of which is usually left in the superheater—account for the low pressure drop.

It is commonly believed that even with superheated steam the pipe walls are covered on the inside with a film of moisture. This is true for low superheat with low steam velocities. At higher superheat and high velocities, however, the wall attains a temperature higher than that of saturated steam, and remains dry.

Examples Showing Advantages of Using Higher Velocities with Superheated Steam

The three following examples from actual practice demonstrate how the possibility of applying higher velocities with superheated steam may be advantageously utilized in reducing the radiation losses and the cost of the piping and covering.

The management of a large textile concern, realizing that it was necessary to lower their power cost, decided as one means to this end to avail themselves of the advantages of superheated steam. Each of the five boilers in the plant was accordingly equipped with superheaters for 200 deg. superheat.

The steam was for use in two engines, one triple-expansion and one compound. The compound engine was located about 950 ft. from the boiler house. The piping between boiler and engine was entirely changed, the old 8-in. piping, being replaced by a new 6-in. line. With the old piping and saturated steam the average pressure drop in the line between boiler and engine was 6 lb. With the new line and superheated steam it was 7.5 lb. The comparatively low pressure drop in the new line was mainly due to the appreciably decreased steam consumption of the engine. The radiation loss of the 8-in. line would naturally be 33 per cent higher than that of the 6-in. line for the same steam temperature.

A chemical company manufacturing aniline dyes had an 8-in. pipe line, 1400 ft. long, in their plant, conveying steam from their boiler room to the process house. An increase in production required the approximate doubling of the steam consumption in the power house, and a second pipe line accordingly was planned. At the same time the use of higher temperatures was found advisable, since the boiler pressure could not be increased appreciably. Superheaters were installed in the boilers, and approximately double the amount of steam superheated was sent through the pipe. Pressure drop was of no consequence, while the radiation loss per pound of steam conveyed was decreased 36 per cent.

A heating plant had two mains 10 in. and 8 in. in diameter and 2300 ft. long. The 10-in. line was used in the cold winter months, while the smaller one was utilized during the remainder of the year. With saturated steam the larger steam demand in the winter months could not be supplied with the small pipe alone, due to the danger of water hammer and excessive vibration, and the larger pipe had to be used. In order to have dry steam at the end of the line, and avoid the losses in liquid heat of the steam condensed in the line, superheaters were installed, and it was found that the greater amount of steam could be conveyed through the smaller pipe without any difficulty. The radiation loss as compared with the 10-in. line was 20 per cent less.

Discussion[1]

Geo. A. Orrok[2] said that the author had once more emphasized that if the outside surface was kept low, and arranged so that it radiated but little, the pipe-line losses would be small. He had covered the velocity of steam in pipes up to 10,000 ft. per min. This was a very ordinary velocity for power plants; in most cases the velocities were greater. It should always be borne in mind that losses were proportional to the surface and not to the amount of steam in the pipe.

J. A. Barnes[3] wrote calling attention to a power plant at Conneaut, Ohio, operating with saturated steam through a pipe line between 400 and 600 ft. long. At this distance it was impossible to operate the engine at anything like its full capacity. Superheaters were installed and about 100 deg. of superheat was obtained at the engine, and the capacity was materially increased. At the Bellman-Brook Co., a finishing company in Fairview, N. J., superheaters were installed which gave from 100 to 150 deg. of superheat, and the output of the plant was increased approximately 35 per cent due entirely to the elimination of radiation losses.

W. H. Armacost[4] said that he had plotted some comparative curves, taking the data from papers presented before the Society by Messrs. McMillan, Bagley, Heilman, and the author. The curve plotted from the data of Mr. Broido's Table 3 bore out his statement that there was less radiation by using superheated steam in pipe lines than with saturated steam, due to the fact that saturated steam, in transferring heat to the pipe wall, partly condensed or gave up some of its latent heat, which heat was not as closely combined with the steam as the sensible heat of a liquid or the heat of superheated steam.

J. H. Lawrence[5] stated that in designing the Hell Gate station, probably the largest in the country, the losses in the steam line had been compared with the losses estimated by various formulas, and while there should have been a very excessive drop in the lines, the loss was only about half that given by any formula in the handbooks, and so small that it was almost negligible.

He did not believe in low velocities. The author mentioned 10,000 ft., but he considered this too low for most steam pipes in a large station. His concern used as a maximum 15,000, and in certain cases, where the lines would only be used in case of an emergency, they did not hesitate to go to 20,000 ft. per min. In most handbooks there were certain rules about velocity which provided for 6000 or 8000 ft. for saturated steam and 10,000 for superheated steam. Such information was very misleading.

Their experience has shown that the velocity should increase as the size of the pipe increased. For one particular case, if a 2-in. pipe was used, the velocity would be around 2000 ft. per min., otherwise the losses would be very excessive. With a 6-in. pipe the proper velocity would be about 6000 ft., and so on. On the 14-in. size they figured about 14,000 ft. velocity as the minimum. They had stopped there, however, as they did not wish to go as high as 20,000 ft. in ordinary practice.

E. G. Bailey[6] said that the steam meter had now become such an integral part of the plant equipment for measuring the output of boilers, steam consumption of turbines and various units as well as the steam distribution, that the conditions suitable for the installation of such meters should be considered not only in the selection of the proper size of pipe but also in the layout.

One meter manufacturer used limiting velocities of $V_{max} = 8000\sqrt{\text{sp. vol.}}$ and another $V_{max} = 10{,}500\sqrt{\text{sp. vol.}}$ With steam at 250 lb. pressure and 200 deg. fahr. superheat having a specific volume of 2.35 the maximum velocities would be 12,240 and 16,000 ft. per minute, respectively. These velocities were capable of being metered accurately only when the steam was flowing through straight pipe of reasonable length on either side of the primary device.

L. B. McMillan[7] stated that it was a matter of common knowledge

[1] These extracts from the discussion deal with those portions of the paper appearing in the preceding abridgment.

[2] Cons. Engr., 17 Battery Place, New York, N. Y. Mem. A.S.M.E.

[3] Superheater Co., New York, N. Y.

[4] Engr., Superheater Co., New York, N. Y. Assoc-Mem. A.S.M.E.

[5] Engrg. Mgr., Thos. E. Murray, Inc., Mem. A.S.M.E.

[6] Bailey Meter Co., Cleveland, Ohio. Mem. A.S.M.E.

[7] Cons. Engr., Johns-Manville Co., New York. Assoc-Mem. A.S.M.E.

that heat was transmitted much more readily from saturated steam to a surface than from superheated steam. However, granting a large difference in transfer coefficients from saturated and superheated steam to pipe wall, the question was, how much difference would this make in actual heat losses?

The value of α for saturated steam used by the author was over twelve times that for superheated steam and it would be only natural to expect that the loss from the saturated-steam pipe would be far larger than that from a superheated-steam pipe at the same temperature. Such would be the case if the transmission of heat from steam to pipe wall were the only factor involved, but the heat must be transmitted from the outside of the pipe to the air, or through insulation to the air. Therefore the additional resistance to heat flow was so great outside of the pipe that the difference in inside resistances became very small in comparison.

In the case of bare pipes there were larger differences, but even with bare pipes the differences were of the order of only 10 per cent. These differences, however, were of little importance as few bare pipes were used for the transmission of superheated steam.

Most published tables on heat losses from bare pipes were based on loss per square foot per degree temperature difference between *pipe surface* and air. These were therefore correct for the stated condition, regardless of what was inside the pipe.

Referring to Table 4, in which a lower radiation loss per pound of steam was shown for superheated steam than for saturated steam, this result was based entirely upon the assumption that the velocity in superheated-steam lines was exactly double the velocity in saturated-steam lines. This table showed higher actual radiation losses on the superheated-steam lines, but on the basis of the doubled velocity so much more steam was passed through the superheated-steam lines that the loss per pound was shown to be less. An explanation of just why the author assumed a doubled velocity in the superheated steam line instead of some other ratio would be necessary in order to give significance to this table.

In fact, it was Mr. McMillan's understanding that the practice of calculating steam-line sizes on an assumed velocity was antiquated and that the preferred method was one based on allowable pressure drop.

L. L. Barrett[8] stated that those engineers who had occasion to consider the heat losses from bare pipe lines conveying steam would be grateful to the author for his presentation of extracts from Eberle's paper which had never before been translated into English.

Referring to the tables in the paper, the heat losses on which Tables 1 and 2 were based had been obtained by weighing the water condensed in the pipe line under test. This method was inaccurate, as stated by the author, and the later determinations of McMillan, Bagley, and Heilman were preferable. The constancy of the value of K for the covered 3-in. line in Table 2 was a good illustration of the inaccuracy of this table. Both McMillan and Bagley had shown that this value would vary considerably with the temperature difference.

The comparison in Table 4 was based on the assumption that all the condensation from the saturated steam lines was wasted. It could not be admitted that this was the general practice in power plant or marine work. In such cases it was almost the invariable practice to return the condensation to the boilers. Any other practice would be most wasteful and would result in a poor showing for the heat cycle of the plant.

It would be interesting to know on what basis the radiation losses for superheated steam in Tables 4 and 6 had been figured where the steam velocities were shown as 7000, 8000, and 10,000 ft. per min., as the highest steam velocity on which data were given in the paper was but 5910 ft. per min.

Referring to the author's summary (appended to the complete paper) no data were given to support the heat-transmission coefficient between steam and pipe wall of 400 for saturated steam there mentioned. The values of this coefficient found in the experiments of Clement and Garland at the University of Illinois ranged from 1649 to 2740 and the value found by McAdams and Frost at the Mass. Inst. of Tech. in 1922 was 2400.

[8] Mgr. Engrg. Dept., Keasbey & Mattison Co., New York, N. Y. Assoc-Mem. A.S.M.E.

The author's conclusion that the coefficient of heat transmission from steam to air remained practically constant up to a temperature of 350 deg. fahr. was disproved by the work of McMillan, Bagley, and Heilman, all of whom showed a very large increase in the coefficient between 100 deg. and 350 deg. fahr. in the case of bare pipe. The increase in the coefficient from 100 deg. to 350 deg. temperature difference was 60 per cent according to Heilman's paper.

The author, in his closure, said that it was very true, as had been stated by Mr. Barrett, that the analysis of radiation losses in pipe lines in the paper was not based on the experiments of Messrs. McMillan, Bagley, and Heilman, all of which were made with electrically heated pipes, and the object of which was mainly to determine the efficiency of various types of pipe covering. His paper was not intended for this purpose. Its object, particularly the first part dealing with radiation losses, was to show, first, that there was a difference between saturated and superheated steam as far as imparting of heat to a pipe wall was concerned; and second, that in comparing the radiation losses of saturated and superheated steam, not the direct heat in B.t.u. was to be considered, but the total heat losses in percentage of the heat conveyed in the steam through the pipe. As the Munich tests were believed to be the only extensive ones conducted with saturated and superheated steam flowing in the test pipe, only these tests could be considered and analyzed in the paper.

Mr. Barrett had looked at the paper only from the standpoint of pipe covering, and therefore had noticed only the data showing the radiation losses. If he would look upon the paper as an engineer and would consider steam velocities, temperature differences, pressure drops, etc., he would better realize the object of the paper and would understand the analysis presented.

Mr. Barrett objected to value of 400 given as the heat-transmission coefficient between the steam and pipe wall because other investigators had found it to be considerably higher, or up to 2700. From Table 1 of the paper it would be seen that at a temperature difference between the steam and the outside air of 250 deg., the heat loss per square foot of surface per hour in B.t.u. was 750. With a heat-transmission coefficient of 400, the temperature of the wall must be $750 \div 400 = 1.875$, or less than 2 deg. below the steam temperature. At a wall temperature equal to the steam temperature, the coefficient would be infinitely large. As it was very difficult to measure accurately the temperature of the steam and the pipe wall, and a difference of 2 deg. was likely to occur, the value of coefficient could not be definitely fixed. Four hundred was mentioned in this paper only as a comparison with the value of superheated steam, which was only 32 at a velocity of about 80 ft. per sec.

As Mr. Armacost had said, the difference between the data of the tests analyzed in the paper and those of Messrs. McMillan, Heilman, and others, was very slight.

Mr. McMillan wondered why the difference between the heat transmission of saturated and superheated steam had been gone into in such detail. As mentioned early in the paper, this subject was of considerable interest as far as the use of superheated steam for heating and drying purposes was concerned. So far as the author was aware, the influence of the velocity of superheated steam on the heat transmission, particularly in connection with the question of whether the pipe was wet or dry inside, had never before been discussed, and was believed to be of considerable interest to engineers.

The velocities taken in Table 4 were in accordance with general engineering practice. The pressure drop was only slightly higher than that for saturated steam and, with the exception of one case, did not exceed 1 lb. throughout the range of the table.

With reference to the question asked by Mr. C. W. Gordon[9] as to why the friction in pipe lines at high pressures was less, while in fittings it was higher than that derived by calculating according to standard formulas for moderate steam pressures, he would say that this was probably due to the fact that in fittings the steam changed its direction and a part of its kinetic energy was lost, and that this was more pronounced at higher pressures than at the lower ones.

[9] Exper. Engr., Superheater Co., New York, N. Y. Jun-Mem. A.S.M.E.

Management Engineering in the Paper Industry

The Measurement of Performance a Factor in Good Management—Industry Should be Organized to Encourage Rather than Repress Individual Development

By R. B. WOLF,[1] NEW YORK, N. Y.

THE most difficult problem that the paper-mill manager has to solve is the problem of overcoming the resistance of the practical operators to the introduction of scientific manufacturing methods. He must depend upon his superintendents, department heads, and foremen for the carrying out of his ideas, and if he can produce in them a desire to improve existing conditions, rapid progress can be made.

The reason the so-called practical operator finds it difficult to follow the scientific or inductive method is that he has not been taught how. The things he knows about paper making he has learned by seeing the things happen. His knowledge, therefore, is made up of a great many more or less disconnected facts, which, due to a lack of scientific training, he has not learned to put together into principles or laws. This in no sense reflects discredit upon the practical man. He has simply lived his life in an environment where it has not been customary to use the scientific method of keeping accurate records of his past experiences. The lack of ability to develop general principles from particular instances can be overcome only if the management encourages the operators, particularly the department heads and foremen, to record the various happenings so that they can be studied in their relationship to one another.

In the past four or five years great progress has been made in measuring the quality elements in paper, and numerical values have been given to such elements as strength, weight, moisture, finish, formation, cleanliness, bulk, and color. In each case a numerical value indicates the nearness to an ideal 100 per cent standard.

One large company has for some time made it a practice to compare the output of each of its mills with the product of a number of outside mills, with whom samples are exchanged, recording in this way the individual performance of each producing unit. Of course such records stimulate interest in the factors which affect the various quality elements. For instance, both weight and moisture are affected by the amount of water in the stock flowing on to the wire of the paper machine, the slowness and freeness of the stock, the amount of agitation in the flow box of the paper machine, the stock proportions in the furnish, the pitch of wire, and many other factors of a similar nature. It is important to note that interest in recording these factors has been aroused by the discovery that the only way to control the quality elements is to control the factors which affect them. This control, however, is not possible, unless the management provides means for keeping individuals who are responsible for variations in quality constantly informed as to what is happening.

The science of paper making in the past has been too much like the old pseudo-sciences, where sense impressions governed. The immense waste attending the use of such methods makes it imperative for us to change them. There is plenty of evidence that the art of paper making is beginning to be based upon real scientific knowledge, and the publication of a complete set of textbooks by the Canadian and American Technical Associations is the best testimony that a genuine spirit of scientific inquiry is developing in the paper industry. As a result of this excellent piece of work it is now possible for the student of paper making to familiarize himself with the best paper-making practices of the past, and the manufacturer can avoid much costly duplication and experiment.

To insure continued progress, however, it is necessary that the group leaders become more skilful in recording and evaluating manufacturing processes. This evaluation of progress, however, is an individual thing and it is therefore necessary to understand the nature of the individual, particularly that very important individual, the superintendent or foreman, who will quite naturally block any effort to introduce methods which he does not himself understand. Any one who has ever tried it knows that scientific record keeping, by technically trained men, will bring to light many practices that should be changed, and this, of course, puts the head of the department on the defensive. He feels that he is *supposed* to know all about his job and in spite of assurances that he could not be expected to know what was not known before, he will, in the great majority of cases, remain on the defensive.

Departmental Cost Sheets Stimulate Economy

Our own experiences have taught us that the best way to produce an open-minded attitude is to introduce a system of departmental cost sheets, which will reflect the economy of operation in each department. No superintendent or department head will object to the introduction of such economy records, and the far-reaching effect of such a cost-keeping system will be seen by a few instances taken from actual experience.

In one plant the introduction of steam meters in order to charge the steam used to each operating department led to such an interest in steam usage that it was possible to avoid the installation of a new boiler, and finally to shut down the spare boiler which it had been previously necessary to keep in almost constant use. The department heads were no longer indifferent to leaky traps on the steam coils, poor insulation on steam pipes, the excessive use of steam in manufacturing processes, etc., for all of the steam used by the department had to be paid for and reflected itself in the cost sheet as uneconomical performance. Not only did the operating department head take an interest in the amount of steam used, but also in the cost of steam. So it followed that the head of the steam department soon found it necessary to know why the cost of making steam was high. Then came the installation of steam meters on each individual boiler unit, and the measurement of coal to each unit so that evaporating efficiency could be determined. Draft gages, CO_2 recorders, etc., of course, followed, for without them the reasons for low evaporation could not be known, but only guessed.

The important thing to remember is that intelligent cost keeping is sure to produce a demand from within the department for the introduction of scientific record keeping which will explain variations in cost, whereas the introduction of scientific methods without first stimulating an interest in economy of operation usually arouses suspicion.

Departmental cost sheets, which show the actual cost of stock in the paper, will soon bring about an inquiry as to the reasons for high shrinkage, and a demand for accurate records of the fiber losses invariably follows. One important development along this line has been the working out of a method for making continuous moisture determinations in the paper coming off the paper machines, making it possible for the machine operator to save stock by not overdrying the paper. The use of this method in the newsprint industry alone has saved literally hundreds of thousands of dollars, for, as shown by the figures of the News Print Service Bureau, an average of considerably over one per cent more paper is now obtained from the same raw materials.[1]

Maintenance of Individuality a Prime Necessity

In his paper on Non-Financial Incentives[2] the author showed the very great savings made in repair materials when cost records were furnished to responsible individuals in a large manufacturing organization, so further illustration is not needed. What it seems to him is needed, however, is a clear understanding of what constitutes individuality. If those entrusted with the direction of our industrial

[1] The R. B. Wolf Company, New York, N. Y., Mem. A.S.M.E.

Contributed by the Forest Products Division for presentation at the Spring Meeting, Montreal, P. Q., Canada, May 28 to 31, 1923, of The American Society of Mechanical Engineers. All papers are subject to revision.

[1] Approximately 2,500,000 tons of news paper is made a year. Assuming an average price of \$35 per ton for raw materials in this paper, a conservative estimate of $1\frac{1}{4}$ per cent increase in the moisture test shows a saving of over \$1,000,000 a year.

[2] Trans. A.S.M.E., vol. 40 (1918), p. 925.

plants do not have a clear understanding of this principle, they cannot effectively instil the principles of sound economics into their organization.

John H. Williams pointed out before the Cost Accountants Association, at Cleveland, that the first thing to do before a cost system is set up is to determine managerial responsibility. Once this is done the group individuality becomes clearly defined and quality and quantity records are sure to follow. Science, in other words, will replace "rule of thumb."

There is, perhaps, no principle of life which is so difficult to understand as this principle of individuality. "Who can tell," says Bergson, "where individuality begins or ends; whether it is the cells which associate themselves into the organism, or the organism which dissociates itself into the cells?" The principle, however, must be understood, for otherwise mankind is doomed to eternal conflict with his fellow-men.

In no other period of the world's history has the group spirit found such material expression as in this twentieth-century development of corporate industry. In the past men have combined into groups for productive purposes, but never before have we seen such grouping of groups and these larger groups into still larger corporate units, and the startling fact is that most of this has taken place within the lifetime of the men who are still in active charge of industry. What is the meaning of it all, and what is to become of the individual men in the process? This, the author believes to be the most momentous problem confronting modern civilization, for if it is not solved, civilization as now constituted cannot last. To crush out the individuality of the workman is fatal to human progress and it is also fatal to destroy the individuality of our manufacturing or producing units.

One of the very first things to recognize about the principle of individuality as related to industry is that it has three modes of expression in any given plant:

First, it expresses itself through each individual worker

Second, it expresses itself through each individual group, or department, which has a specific function to perform; and

Third, it is expressed by the plant as a whole.

The next thing to recognize about individuality is that its purpose is to record a lapse of time. Progress must be made from one point in time to another point in time, and it is the very essence of individuality to preserve a record of the changes which have occurred between a sequence of time periods. To illustrate: the year is usually divided into twelve monthly periods and for each month we have records of Quantity of Paper Produced, Quality of Paper Produced, and Cost of Paper Produced. It is only by studying these records of *past* performance of the plant as a whole that we can get a sense of what has been accomplished and, what is more important, a vision of what may be accomplished in the future.

The plant, however, is made up of departments, each of which contributes its individual share to the enterprise. Therefore, to get the most effective results, similar monthly records should be kept for each department, such as the quantity, quality, and cost of pulp produced; the quantity, quality, and cost of steam produced; or the quantity, quality, and cost of the output of each department of the plant.

Finally, all departments are composed of individual men and we have found it equally necessary to the cause of sane and rational progress to record for the workman's benefit the quantity, quality, and cost of performing his work. It is not always practical to record all of these factors, but always one can be recorded, sometimes two, and sometimes all three. It goes without saying that the workman who is conscious of all three will see how his own job is related to the process as a whole and can work with a much greater degree of intelligence.

The periods or points in time between which the records enable us to note changes, vary in both duration and frequency of occurrence. In processes where rapid changes occur, as in the weight of paper on paper machines, or temperatures in cooking digesters, the periods are short and are usually measured by minutes; in the case of average temperatures, paper-machine speeds, or evaporation records the periods are longer and are measured by hours; and in the case of many quantity, quality, and cost records the periods represent averages for days, weeks, or months.

In each case, however, it should be noted that we are measuring the progress of a producing unit and that these individual producing units are either men, groups (operating departments or divisions), or the plant as a whole.

It is not difficult to visualize the concrete reality of the first of these producing units, the man. It is difficult, however, to visualize the essential unity of the department or the unity of the plant itself, of which the department is an individual member.

There is perhaps nothing more concrete and practical and at the same time more abstract and theoretical than this problem of developing these indivisible group individualities. The author feels sure that the way out is to come to a realization that the purpose of the individual is to create, whether the individual is a *man* creating (converting) pulp from wood on a grinder, a *department* creating chlorine liquor from salt and lime, or a *plant* creating paper from wood, clay, size, color, and all the various raw materials which furnish the energy or the substance used in the manufacturing process.

As indicated before, the answer seems to lie in increasing our skill in recording and evaluating the manufacturing process, so that consciousness of what has happened in "times" past may stimulate an interest in improvements to be made in "times" to come.

Just as the man's interest in the future economy of his own performance is aroused by making him conscious of the economy with which he has performed in the past, so must the group consciousness of economy be aroused by providing a record of past group performance. Unless group individuality (*esprit de corps*) is developed there can be no sense of responsibility and hence no progressive group accomplishment. It is obvious, therefore, that we must develop records for enabling the individuals who comprise the group to be conscious of what the group, *as a unit*, is accomplishing. Without this definite knowledge of progress made there can be no coöperative teamwork and the progress will be in the direction of quantity, with little thought of improvement in quality of performance or economy of operation.

What is true of the group or department is of course equally true of the plant as a whole, so each individual department must be conscious of the effect of its own activities upon the finished product. The point that must not be lost sight of is that this is not possible without a constant recording of the effect of variations in departmental products upon the finished product.

Quantity, quality, and cost should all be recorded, and if these records are kept *of* men, departments, and plant and made available *to* men, departments, and plant, there will be released very great creative power in the only way it can be released, namely, through the individual, whether that individual be a *man*, a *department*, or a *plant*.

"Our social economic system cannot march toward better days unless it is inspired by the things of the spirit. It is here that the higher purposes of individualism must find their sustenance."[1] Herbert Hoover, who says this, has a concrete record of accomplishment to his credit which makes these mystical words take on new meaning, especially when taken with his expressed conviction that "permanent spiritual progress lies with the individual."

Yes, the individual must be understood, and the whole problem of industry, it seems to the author, resolves itself into finding out how to enable the unit individual, the man, to become conscious of his relationship to the all-including group individual, the plant; and how to organize the plant so that it will be sufficiently sensitive to the welfare of the human units of which it is composed that it will not repress but encourage their individual development.

The secret seems to lie in stimulating group consciousness within the organic whole of the plant by continuously recording the group's relationship to the plant on the one hand, and the man on the other, and the immediate need seems to be for the education of foremen to intelligently direct the groups. This education, however, to be of use, must be largely obtained from a study of records of group experiences, for information obtained in this way constantly stimulates the individual to greater effort. The recorded results of this new effort will act again as a fresh stimulus, so that continuous progress in both knowledge of process and skill in the use of his knowledge is bound to follow.

[1] American Individualism, by Herbert Hoover, published by Doubleday, Page & Co.

The Oil Venturi Meter

Measurement of the Flow of Viscous Fluids with the Venturi Meter—Decrease of Coefficient with Turbulence—Influence of Viscosity—An Accurate Method of Calibration

By ED. S. SMITH, JR.,[1] LOS ANGELES, CAL.

THE venturi meter furnishes a means for accurately measuring the flow of liquids and gases in pipe lines within certain limits. These limits, however, must be known, and they are determined by the corresponding values of the turbulence, also known as Reynolds' criterion and defined by the method of dimensions as Qg/du. In the following paragraphs the author presents an accurate method of calibrating the venturi meter, shows the limit for accurate measurement, and brings out the fact that the viscosity of the fluid has considerable effect and must be accurately known. The theory underlying the method described is not essentially new, but has been discussed by W. J. Walker and W. N. Bond as noted in references at the end of the paper.

In order to use the venturi meter with accuracy there must be known not only the size and form of the tube but also the viscosity and density of the fluid. There are several standard viscosimeters in common use in the oil industry which are used to determine the viscosity of liquids with commercial speed and sufficient precision.

The values of the coefficient of the venturi meter have been determined for a wide range of turbulences. The coefficient approaches unity at high turbulences but drops rapidly just above the upper critical turbulence and approaches zero as the turbulence approaches zero. This falling off of the coefficient is due chiefly to the increase of the friction pressure loss of the tube relative to the theoretical pressure drop, i.e., that pressure drop causing the increase of velocity from the entrance to the contracted throat of the meter.

Fig. 3 is an example of the most convenient form of calibration for actual use, and is the result of two years' use of this method of calibrating the venturi meter with viscous oils.

Calibration by the Method of Dimensions

The increasing use of continuous processes in the oil-refining and other industries is bringing the venturi and other continuous flow meters into common use for the measurement of a large variety of fluids. As the viscosity of liquids may now be commercially determined, it is possible to use these meters with a method of calibration which is both simple and exact.

The method of dimensions has been in use for several years in the computation of friction pressure loss in pipe lines carrying viscous oils.[2]

The calibration has been extended to low values of the turbulence by employing data obtained by the author in tests conducted on a model venturi meter at the University of California. Grateful acknowledgment is made to Dr. Baldwin M. Woods, professor of aerodynamics, and to L. C. Uren, professor of petroleum technology, both of that institution, for their generous assistance.

The symbols and formulas used are as follows:

- Q = quantity, U.S. gal. per min
- q = quantity, cu. ft. per sec.
- u/g = kinematic viscosity, sq. cm. per sec.
- u = absolute viscosity, grams per cm-sec.
- g = density (specific gravity, approximately), grams per cu. cm.
- d = diameter of pipe, i.e., the same as the approach to the venturi tube, in.
- a = cross-sectional area of pipe, sq. ft.
- H = differential head of liquid in venturi tube from the approach to the throat, ft.
- h = differential head of mercury in manometer measuring H, in.
- C = coefficient for the venturi meter, see Equation [1]
- P = friction pressure loss in pipe line per 1000 lin. ft., lb. per sq. in.
- k = coefficient for friction pressure loss in pipe line, see Equation [2]

$$q = C \times a_2 \times \frac{a_1}{\sqrt{a_1^2 - a_2^2}} \times \sqrt{2 \times 32.2 \times H} \quad \ldots\ldots [1]$$

$$P = k \times g \times \frac{Q^2}{d^5} \quad \ldots\ldots [2]$$

Fig. 1 shows the value of the venturi-meter coefficient C as determined by actual experiments over a range of turbulence from 0.0003 to 200,000.

The friction-pressure-loss coefficient for pipe lines is also shown, the lower critical turbulence a occurring at 64 and the higher critical turbulence b at 85. From zero to 64 the flow is known as "viscous" or "streamline" flow, and the friction loss varies as the first power of the velocity. From 64 to 85 the flow may be termed "superturbulent," as the friction pressure loss varies as the cube of the velocity. From 85 to infinity the flow is known as "turbulent" or "hydraulic," and the friction pressure loss varies as a power of the velocity (the 1.75 power for smooth steel pipe lines such as are ordinarily used for oil transportation), with the square of the velocity as the upper limit for very rough pipe.

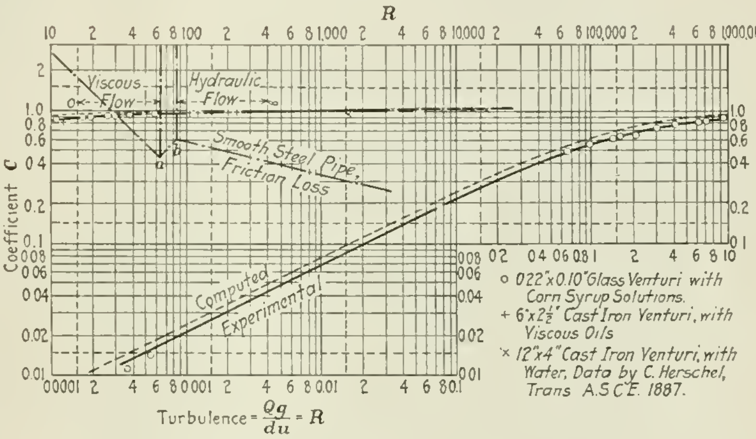

Fig. 1 Values of Venturi-Meter Coefficient C as Determined over a Range of Turbulence from 0.0003 to 200,000

As the coefficient of the venturi meter is partly dependent upon the friction pressure loss along the venturi tube, it is apparent that the law of variation of the coefficient with the turbulence will not be the same for the three types of flow and that consequently the graphical method of handling the coefficient is preferable to the use of an algebraic formula.

Fig. 2 provides an accurate calibration for the two types of venturi meters in common use in the United States, the Builders Iron Foundry and the Simplex Standard.

The Builders Iron Foundry tube has faired lines and consequently the higher coefficient. This calibration is for meters having a ratio of approach diameter to throat diameter of approximately 2.5 to 1, and is strictly correct for a 6-in. meter only—larger sizes having slightly higher coefficients and smaller sizes slightly lower coefficients. However, it is accurate enough for oil measurement under commercial conditions.

The Simplex Standard tube has a ratio of diameters of 2 to 1, and all sizes are made closely similar in form. The sharper changes from the cylinders of the approach and throat to the cone cause the coefficient to be slightly lower than for the other type of meter, but its accuracy is as high since it is necessary with both types of meter to use a calibration when measuring viscous oils.

Example in the Use of Fig. 2. Determine the quantity of oil flowing at 130 deg. fahr. through a 6-in. by 2½-in. venturi tube (Type B.I.F.) when the mercury-oil differential h = 4.2 in., the kinematic viscosity u/g = 0.11 sq. cm. per sec. (from 64 sec. Saybolt), the density of the oil flowing is g = 0.90 gram per cu. cm. (from 26 deg. B.), and the density of the same oil at 60 deg. fahr. above the mercury in the manometer is 0.94 gram per cu. cm. (from 20 deg. B. at this temperature).

[1] California National Supply Co.

[2] See The Friction Pressure Loss in Oil Pipe Lines, compiled by R. S. Danforth and published by the Kinney Mfg. Co., of San Francisco, Cal.

Presented at the Pacific Coast Regional Meeting of The American Society of Mechanical Engineers, Los Angeles, Cal., April 16–18, 1923.

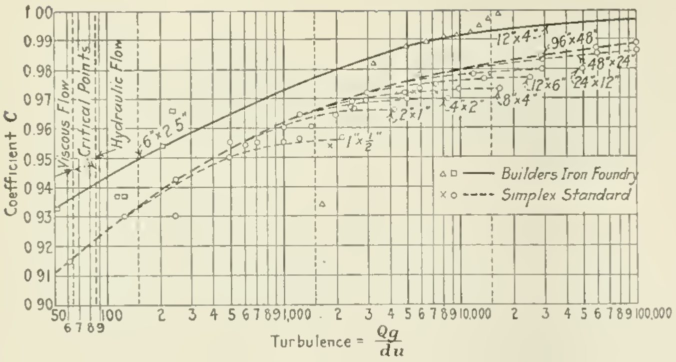

Fig. 2 Calibration for Two Types of Venturi Meters in Common Use in the United States

Since $d_1 = 6$ in., $a_1 = 0.196$ sq. ft.; also, from $d_2 = 2\frac{1}{2}$ in., $a_2 = 0.0341$ sq. ft. Substituting these volumes in Equation [1],

$$q = C \times 0.0341 \times 1.016 \times 8.02 \times \sqrt{H}$$

$$= C \times 0.278 \times \sqrt{H} \text{ cu. ft. per sec.}$$

For a first approximation, assume $C = 0.95$; then

$$Q = 448.9 \times 0.95 \times 0.278 \times \sqrt{\frac{13.6 - 0.94}{12 \times 0.90}} \times \sqrt{4.2}$$

$$= 263 \text{ gal. per min.}$$

But $Qg/du = \frac{263}{6 \times 0.11} = 400$, and from Fig. 2, $C = 0.962$; therefore

$$Q = 0.962 \times 278 = 267 \text{ gal. per min.}$$

which is the quantity flowing under the conditions stated above.

Fig. 3 consists of *Q-h* curves for each of several viscosities of oil. The full lines are accurate to 1 per cent. The broken lines are in the viscous-flow region and are of undetermined reliability. The density correction for the head *h* is applied by the graph at the left side of the figure. A graph for the conversion of Baumé density to specific gravity (density in grams per cu. cm.) is attached to the upper side of the density-correction graph and shows the correction for the increase of density with a rise of temperature of the oil above 60 deg. fahr. At the right of the density-temperature graph is a small sheet of logarithmic cross-section paper for plotting viscosities at various temperatures of the oil which is being measured. The kinematic viscosity of ordinary petroleum oils, when plotted against temperature on logarithmic cross-section paper, forms a nearly straight line. As an example three plotted points are shown for a viscous California oil. At some higher temperature than 200 deg. fahr., this line is discontinuous for most petroleum oils and another nearly straight line holds for higher temperatures. The conversion from Saybolt viscosity to kinematic viscosity is given on the upper margin of this graph. The viscosity of oil at any temperature, as shown on this graph, is used to indicate the proper curve to use on the *Q-h* graph. This same group of auxiliary graphs may be used with any size of venturi meter, it being necessary to change only the *Q-h* graph.

Example in the Use of Fig. 3. Determine the quantity of oil flowing under the same conditions as in the example illustrating the use of Fig. 2.

Referring to Fig. 3, follow the arrowed dot-and-dash line for the 4.2-in. mercury-oil deflection from the left side of the density-head diagram to the 0.90 vertical density line, then up the diagonal to the corrected deflection $h = 4.68$ in. Follow this horizontal dot-and-dash line to its intersection with the diagonal 0.11 kinematic viscosity line (obtained by interpolation). Reading vertically down from this intersection it is seen that the quantity of oil flowing under these conditions is 267 gal. per min.

Limits of Accuracy of the Calibrations

The data submitted in Fig. 2 for the Builders Iron Foundry venturi tube are accurate to within 1 per cent for tubes of similar form (2.5:1 ratio of approach to throat diameter) for 2-in. to 12-in. diameter tubes in the region of turbulent flow, since the data in this region are calibrations of full-size venturi tubes with lathe-turned bronze or cast-iron throats.

This calibration applies strictly to 6-in. diameter tubes only; because the tubes to be similar in form must have the roughness increase directly with the size of the tube, i.e., the size of the rugosities must be in proportion to the diameter of the tube. The use of equally rough (or smooth) surfaces for all sizes of meters causes the coefficient to be slightly higher for larger meters for all turbulences in the region of turbulent flow. The degree of roughness does not appreciably affect the coefficient of the venturi tube in the viscous-flow region.

The data in the viscous-flow region are not as accurate as those in the turbulent-flow region. The former are from a calibration made by the author on a 0.22-in. by 0.10-in. home-made model glass venturi-meter tube with water and corn-syrup solutions. The venturi tube was drawn from a straight glass tube and, while not exactly similar in form to the Builders Iron Foundry tubes, approached it closely enough to show definitely the type of variation of the coefficient to be expected for full-scale venturi tubes. The kinematic viscosity was determined with home-made pipette viscosimeters calibrated with water. In spite of the care used to avoid the effects of surface tension and velocity head, and because these viscosimeters measured solutions more than a thousand times as viscous as water, the probable accuracy of the viscosity determinations is approximately 90 per cent. This would mean an expected error of about 10 per cent in the turbulence for the values of the coefficient in the viscous-flow region.

For the purpose of checking the viscous-flow data obtained with the model glass venturi tube, the theoretical coefficient of a 6-in. by 3-in. Simplex venturi tube was computed. It was assumed that the only sources of loss of head from the approach to the throat were those due to the friction loss along the tube and the building up of the kinetic energy of the fluid in the throat. Poiseuille's formula for the friction loss of fluids in viscous flow in cylindrical tubes was used without modification for the approach and the throat. The friction loss in the cone was computed using the integral calculus and the same formula. From the sum of the change

(*Continued on page 331*)

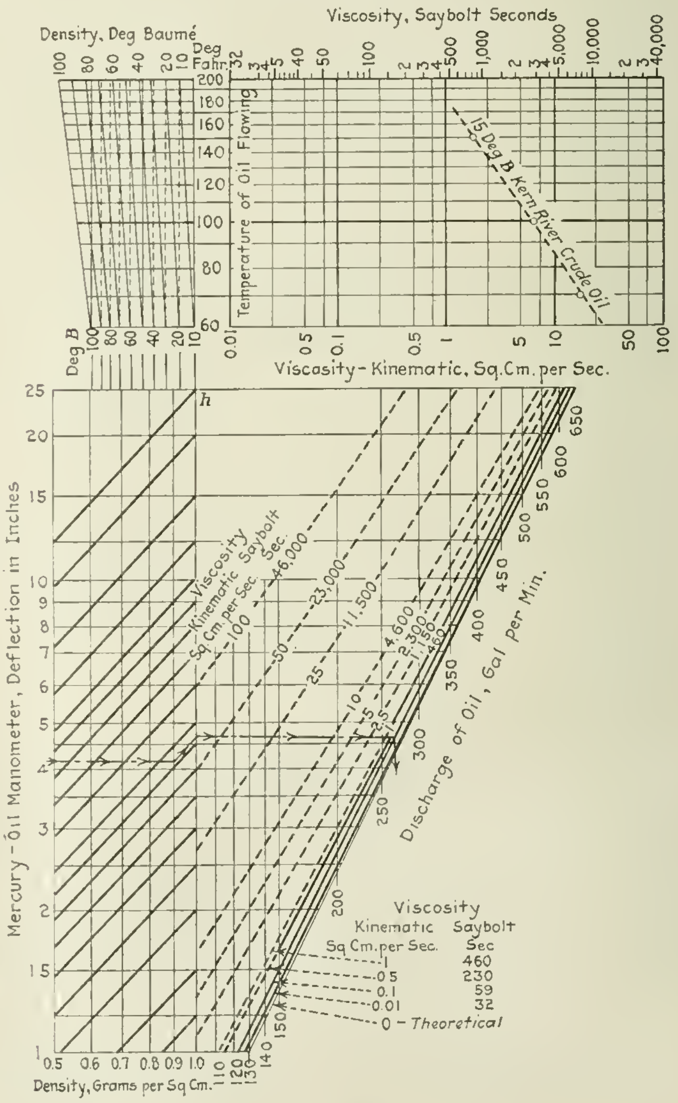

Fig. 3 Flow Graph for a 6-in. by $2\frac{1}{2}$-in. Builders Iron Foundry Venturi Meter

Boiler-Furnace Design

The Tendency in Modern Power Stations Toward Larger Combustion Space—Factors Governing Furnace Volume—The Construction of Boiler-Furnace Walls

By EDWIN B. RICKETTS,[1] NEW YORK, N. Y.

THE FUNCTION of the boiler furnace is to supplement the grate or fuel burner in transforming the energy of the fuel into heat and to transfer that heat to the boiler; and the measure of the efficiency of a furnace is the degree of completeness of combustion at the point where the gases enter the boiler tubes and the degree of availability for absorption by the boiler of the potential heat in the fuel at the point where it is delivered to the boiler for absorption—in other words, the percentage of excess air which is necessary to produce complete combustion at the point of exit from the furnace.

Last fall in connection with the preparation of the Stokers and Furnaces Section of the Prime Movers Committee Report, the author undertook an investigation for the purpose of determining what relation, if any, existed between the relative volume of the furnace and the efficiency of a boiler. This investigation occupied most of the time of several men for three or four months, but in spite of the large amount of time and thought expended, none of them was able to draw any definite conclusions from the data available. However, the importance of and general interest in the question justify reviewing briefly some of the facts which this investigation has so far brought to light in the hope that by broadening the field of the investigation others may solve the problem where, due to his lack of information, the author has been unsuccessful. A few years ago it was a very rare thing to find boilers provided with more than 1 to $1^1/_2$ cu. ft. of furnace volume per rated hp., but the tendency in modern power stations is very strongly toward much larger combustion space. An idea of what is becoming general practice today may be obtained from Table 1, which gives the cubic feet of furnace volume per rated hp. in a number of our newest power stations. In the chain-grate stoker field it will be noticed that this ratio runs from 2 in the case of the American Sugar Refining Company's plant in Baltimore to a maximum of 5.75 at Waukegan. With underfeed stokers it varies from 2.17 at Dodge Bros. to 4.80 at the Delaware station. With pulverized coal at Lakeside 4.56 cu. ft. was provided, which is being increased to 6.52 at Cahokia, and the author knows of installations at present still in the preliminary stage which will probably have a ratio as high as 10.

TABLE 1 CUBIC FEET OF FURNACE VOLUME PER RATED HORSEPOWER (10 SQ. FT. BOILER HEATING SURFACE)

Station	Chain-grate stokers	Underfeed stokers	Pulverized coal
Recent Stations			
American Sugar-Baltimore	2.00	..	..
Kansas City	2.57	..	..
Dalmarnock-Glasgow	3.10	..	..
Barking-London	3.87	..	..
Calumet	4.45	..	..
Waukegan	5.75	..	..
Dodge Bros.	..	2.17	..
Seward	..	3.24	..
Colfax	..	3.45	..
Springdale	..	3.95	..
Hell Gate	..	4.23	..
Gennevilliers-Paris	..	4.50	..
South Meadow	..	4.56	..
Delaware	..	4.80	..
Lakeside	..	..	4.66
River Rouge	..	..	4.98
Cahokia	..	..	6.52
Older Stations			
Waterside	..	1.05	..
Essex	..	1.95	..
Muscle Shoals	..	2.19	..
L. Street	..	2.43	..
Connors Creek	..	2.72	..

Table 2 gives, so far as the author has been able to learn, the highest B.t.u. fired per cubic foot of furnace volume per hour on tests where the efficiency of boiler furnace, grate, and superheater was approximately 80 per cent (78 to 82 per cent). Of the coal-firing systems pulverized coal is seen to require by far the largest furnace volume, whereas the same efficiency has been obtained on hand-fired Scotch marine boilers when burning seven times as much coal per cubic foot as has been found best suited for powdered-coal installations.

Factors Governing Furnace Volume

The furnace volume required for the complete combustion of any fuel is a function of many variables, among the more important of which may be mentioned the physical state and chemical composition of the fuel, the type of fuel-burning equipment used, the shape of the combustion chamber, and the means provided for mixing the fuel and air in the furnace.

Physical State and Chemical Composition of the Fuel. On account of its chemical composition and physical state fuel oil when burned in modern mechanical atomizer burners is almost ideal in the furnace volume required for its complete combustion. As much as 265,000 B.t.u. per cu. ft. per hour has been obtained on a White Foster boiler with an efficiency of 76 per cent. This is due to the fact that a large part of the work which in old-style burners was performed by the furnace is now accomplished in the burner itself. Oil is heated to about its flash point and blown into the furnace thoroughly atomized and mixed with the requisite quantity of air for combustion, resulting in a very sharp and intense flame accompanied by complete combustion within a few feet from the mouth of the burner.

Next in order to oil are the lump grades of low-volatile coal. With fuel of this kind the greater part of the combustion takes place within the fuel bed itself or within a very short distance above it. The gas and air leaving the fuel bed are thoroughly mixed and very little furnace volume is required for the completion of combustion. With the higher-volatile solid fuels, particularly if they are fired in the form of slack, large amounts of gaseous products are distilled from the fuel bed and frequently the air and gas are in a more or less stratified form, requiring either a considerable distance of travel or the provision of certain mixing arrangements in order that the gas may be completely consumed before reaching the cooling surface of the boiler.

Type of Fuel-Burning Equipment. Of the types of mechanical fuel-burning equipments in common use, the mechanical atomizer oil burner, for the reasons stated above, requires the least help from the furnace. Next in order probably comes the underfeed type of stoker. In underfeed stokers provided with means for continuous ash discharge, due to the depth of the fuel bed and the multiplicity of air openings, a large part of the combustion takes place on the grate and a fairly uniform mixture of air and gases is delivered to the furnace so long as the fire is kept free from holes and large clinkers. Some stratification may take place when too much air is admitted from side-wall ventilating systems, but this difficulty is usually easily overcome by altering the size and position of these air openings.

TABLE 2 B.T.U. FIRED PER HOUR PER CUBIC FOOT OF FURNACE VOLUME AT EFFICIENCIES OF ABOUT 80 PER CENT WITHOUT ECONOMIZERS

Fuel-burning system	B.t.u. per cu. ft. of furnace volume
Pulverized coal	22,000
Chain-grate stokers	37,500
Underfeed stokers	64,000
Locomotives	70,000
Oil—steam atomization	85,000
Scotch marine boiler, hand-fired	144,000
Oil—mechanical atomization	176,000

Chain-Grate Stokers. That part of the combustion which takes place on the grate of a chain-grate stoker is considerably more complicated than it is in the case of an underfeed type of stoker. Fuel enters the furnace at the front end of the grate where it must be ignited by reflected heat from an incandescent arch. In this ignition process large volumes of gas are driven off and there is usually a considerable deficiency of air. As the fuel passes further on into the furnace fairly complete combustion takes place on the

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Presented at a meeting of the Metropolitan Section of The American Society of Mechanical Engineers, New York, March 27, 1923. Slightly abridged.

grate in the center zone, while in the rear end of the stoker the last of the carbon is burned out, accompanied by a considerable excess of air. There are thus three streams of gas leaving the grate, each being very different in composition, ranging as they do from a stream of gas at the front end mixed with insufficient air for combustion to another mixed with a large excess of air at the rear of the furnace. If provision is not made in the furnace for bringing together and mixing these gaseous streams incomplete combustion may result, as well as a large excess of air.

Pulverized-Fuel Systems. In the systems for burning pulverized fuel which are finding the most successful applications today, the fuel together with probably 25 or 30 per cent of the air requisite for combustion is wafted into the furnace in such a way as to give it as long a travel as possible before reaching the tubes, and the air necessary to complete combustion is brought into the furnace through a multiplicity of openings so arranged as to bring fresh streams of air in contact with the coal particles at successive intervals as they travel through the furnace; while the particle of powdered coal is very small, if it is to be consumed with a minimum of excess air, it is obvious that it must have a long period in the furnace in order to find and combine with those air molecules which are provided for its combustion.

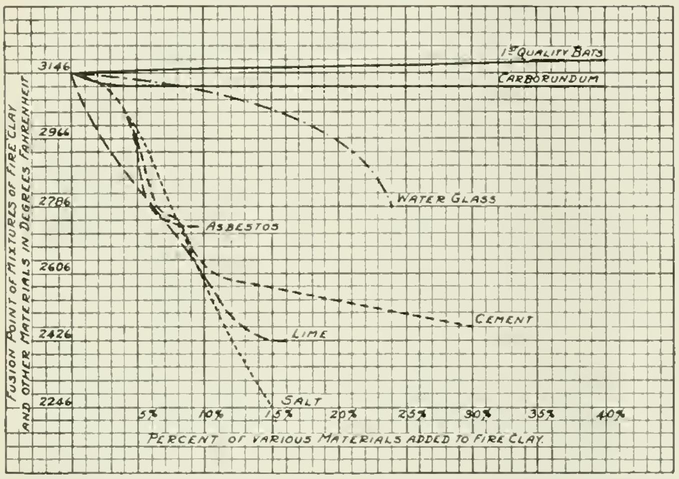

Fig. 1 Effect on the Melting Point of the Resulting Mixture of Adding Various Materials to Fireclay

Shape of Combustion Chamber and Mixing Arrangements. It is obvious that a thorough mixture of the fuel and air must take place somewhere in the burning system. If this is not done by the burner or grate, it must be brought about within the furnace. In the mechanical atomizer oil burner practically all of the mixing is done in the burner itself. Consequently no mixing arrangements are required in the furnace. In the underfeed stoker a number of arch and steam-jet mixing schemes have been tried, but it has usually been found that complete combustion will take place without any special mixing device if sufficient height of furnace is provided between the grates and the tubes. With chain-grate stokers an ignition arch is always provided and frequently a reverse arch over the rear end of the stoker; in some cases a third arch is added over the center of the combustion chamber in order to mix the gaseous streams coming from the three main subdivisions of the grate, and it has usually been found that better results can be obtained the more elaborate the mixing system provided. In the powdered-coal systems now in general use very little of the mixing is done in the burner. There are a number of systems which have been used in an experimental way, in which a much larger proportion of the mixing is done in the burner. With these systems it is claimed that a much smaller furnace volume will be required than is now considered necessary, and while it is hoped that the advocates of these systems will be successful in demonstrating this statement, so far they have not done so on any commercial scale.

On account of the variations in the work which the furnace has to do when used in connection with the various fuel-burning systems, it is obviously impossible to make any general comparison of the effect of furnace volume on efficiency. Consequently the effect of furnace volume must be studied separately for each of the systems. Very much more reliable test data were available on plants using underfeed stokers than with any other class of equipment, and it was found possible to plot quite a large number of tests where underfeed stokers were used in connection with 14-high Babcock & Wilcox boilers. None of these furnaces was complicated by arches or other mixing devices, thus eliminating a large number of variable elements, and while the curves show a slight tendency toward better efficiency with higher furnace volume, the information is by no means conclusive and the difference indicated may easily be accounted for by test errors or differences in skill of the operators. Furnaces having 3 or 6 cu. ft. per rated hp. cost a great deal more to build and to maintain than furnaces of smaller sizes. Personally, the author has always been an advocate of large furnaces and it would seem, judging from the results given in Table I, that most of those who have to do with the construction of modern power plants agree with him on this point. Engineers should be in a position to prove that any extra expenditure which they make in construction or maintenance is justified by the better economies obtained.

The Construction of Boiler-Furnace Walls

In considering this subject the first two questions which present themselves are, why is a wall needed around a boiler furnace, and what are some of the more important characteristics which a perfect wall should possess? A wall is needed around a furnace to direct the heat produced by the burning fuel to the surfaces provided for absorbing it, to prevent this heat from being dissipated in all directions where it would be wasted, and to prevent excess air from entering the furnace and commingling with the products of combustion.

A perfect wall would then be one which, under all conditions of service, would be impervious to the flow of gas, air, or heat units; it would not crack, spall, or soften, and would not be injured by molten slag.

It is well known that our walls fail to meet fully the above requirements and we may profitably consider for a few moments some of the reasons for the shortcomings of present-day walls and some of the ways in which these shortcomings may be overcome.

In Table 3 are given some of the principal characteristics of refractory materials. It would seem at first glance that from this list an almost ideal combination of materials could be selected, and if cost were no object the construction of good boiler walls would be greatly simplified. Unfortunately, however, the cost of some of the more desirable materials is such as to prohibit their use except in small quantities for special purposes. Cost and distribution of raw materials make it necessary to rely on fireclay products for the bulk of our boiler-wall work.

While the firebrick themselves may fail in a number of ways (several of which ways will be discussed later), usually the weakest part of the wall is the jointing material. Up to the present time fireclay of approximately the same composition as the brick has usually been found to be the most satisfactory material with which to bond the wall, and this material is always more easily disintegrated than the firebrick. Consequently it is advisable that firebrick be obtained with as close uniformity in dimensions as possible so that the amount of jointing material may be reduced to a minimum.

Many attempts have been made to obtain a material better suited to this purpose than fireclay, and, while some of these compounds have given very satisfactory results under certain conditions, in many cases the user is paying an exorbitant price for a material having refractory qualities inferior to that of fireclay which forms the base of most of these so-called high-temperature cements. Fig. 1 shows the effect on the melting point of the mixture resulting from the addition of various materials to fireclay.

The present-day tendencies in power-plant practice are very materially increasing the severity of the conditions under which refractories are used in boiler-wall construction. These tendencies are the result of the increasing cost of fuel, labor, and equipment, which has made profitable economies in all three of these items which were not to be thought of a few years ago and may be briefly summarized as follows:

1 In order to reduce the amount of boiler equipment for a given output the rate of operation has been largely increased, bringing

about increases in furnace temperature and the area of walls exposed to high temperature.

2 Furnace walls are much tighter than formerly and are in many cases protected from radiation and air infiltration by layers of heat insulation and airtight steel casings, causing dangerous temperatures to penetrate much more deeply into the walls than was the case with the type of construction used a few years ago.

3. The reduction of excess air to a minimum and the conservation of low-level heat by preheating the air for combustion, a practice which is common in Europe and which is meeting with increasing favor in this country, will probably add several hundred degrees to present furnace temperatures.

An idea of the temperature gradient through boiler-furnace walls can be obtained from Fig. 2 which shows the temperature in the walls at the Delray station of the Detroit Edison Co. These walls are solid firebrick 28 in. thick with no insulation or steel casing. The tests were made with a slight draft inside the setting, at low ratings, the draft being increased with the rating. Considering these results, which were very accurately obtained by embedding thermocouples in the wall at various distances from the fire face,

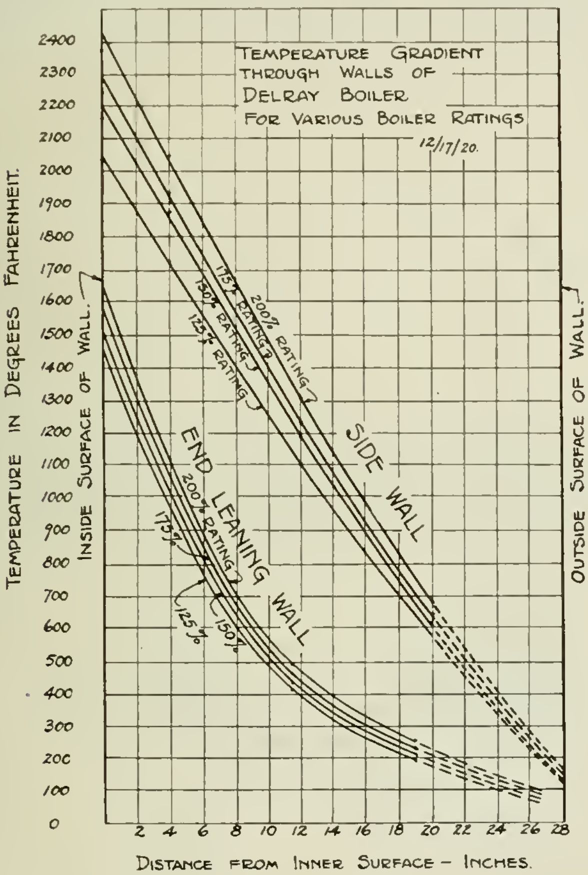

Fig. 2 Temperature Gradient through Walls of Delray Boiler for Various Boiler Ratings

it can readily be seen that when ratings are pushed up to 400 per cent with the addition of possibly 200 deg. by air preheaters a furnace-wall temperature close to 2900 deg. fahr. will result if we continue to use the type of wall construction now generally employed.

Furnace-wall temperatures are affected to a considerable extent by the relative pressures on the two sides of the wall. This effect is clearly shown by some tests made by R. M. Howe on an experimental furnace at the Mellon Institute.

The temperature of the furnace wall was measured at a point 1/2 in. back from the inside edge of the furnace under varying conditions of draft in the furnace with results as follows:

The furnace temperature was 2440 deg. fahr., with a slight draft the wall temperature was 2030 deg., with 0.05 in. pressure 2300 deg., and with 1 in. pressure it rose to 2380 deg. The importance of avoiding a positive pressure in boiler furnaces cannot be overemphasized as it is one of the most prolific causes of wall failure.

Assuming that the furnace wall has been skillfully constructed with high-grade fireclay materials, what are the principle causes of wall failure, and how may they be avoided?

As shown in Table 3, the melting point of first-class fireclay refractories is well above furnace temperatures of which there is

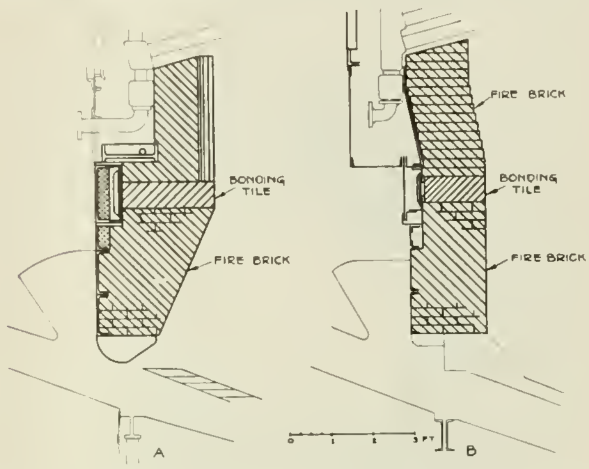

Fig. 3 (A) Section through Front Wall of Underfeed Stoker that Failed after a Few Weeks' Use, and (B) Section of Wall Replacing It, Which has Given Good Service for Several Years

any immediate prospect; consequently, except in cases where an oil or gas flame impinges directly against the furnace wall, a condition which is usually readily remedied by the selection of suitable burner equipment, there will be little trouble from straight fusion of the furnace lining.

Again referring to Table 3, it is seen that fireclay bricks begin to soften under load at 500 to 600 deg. below their melting point. With the old-style low-set boilers this was not a very important feature because the surface exposed to high temperatures was small and the superimposed loads light. With modern high-set boilers, however, this characteristic of firebrick has assumed increasing importance. The liability to failure from this cause is a function of the depth of penetration in the wall of a temperature which would cause softening and of the shape of the wall. A study of Fig. 3 will show what is meant by the latter statement. To the left is shown the front wall of an underfeed stoker setting which is corbeled in such a way as to impose a very heavy load on the course of brick just above the ram-box caps. It will be readily seen that a slight softening of the lower rows of brick will cause the whole front wall to fall into the furnace. The life of this wall was only a few weeks and it has been replaced by the one on the right which has given several years' service with no trouble.

A study of a large number of reports on the life history of walls all over the country has indicated that the wall which leans in toward the furnace is a constant source of trouble.

The erosion of firebrick by molten ash is responsible for more furnace-wall failures than all the other causes put together. Where coals are used having a high ash-fusion temperature, say 2700 to 2800 deg. fahr., ash erosion is not important; but such coals are scarce now and are becoming more so every day, and furnaces must be so constructed that they will function successfully with coals the ash of which begins to soften at 2100 deg. and runs at 2300 deg.

The effect of ash erosion is most pronounced where a pulverized-coal or forced-draft-stoker flame strikes the furnace wall. These flames carry small particles of molten ash which penetrate any cracks or pores in the brickwork. The surface of the wall then

TABLE 3 THERMAL PROPERTIES OF VARIOUS REFRACTORIES

Material	Fusion point, deg. fahr.	Point of failure under 50 lb. per sq. in. load, deg. fahr.	Thermal conductivity at 1832 deg. fahr., B.t.u. per hr. per deg. fahr. per inch	Specific heat at 212 deg. fahr.	Resistance to spalling
Fireclay	3092	2462–2552	11.3	0.199	Good
Silica	3092	2912	12.7	0.219	Poor
Magnesia	3929	2696	22.9	0.231	Poor
Chrome	3722	2597	16.5	...	Poor
Bauxite	3245	2462 or more	11.3	...	Good
Zirconia	4667	2750	Low	...	...
Carborundum	4064	Above 3002	67.0	0.186	Good
Alundum	3722	Above 2822	High	0.198	Good

becomes a mixture of firebrick and ash, which has a melting point much lower than firebrick.

Coal ash is not a definite chemical compound but a mixture of many compounds. It consequently has no definite melting point like ice but changes state gradually, there frequently being an interval of 200 to 300 deg. between the first signs of softening and the point where the viscosity has been so reduced that it will readily flow.

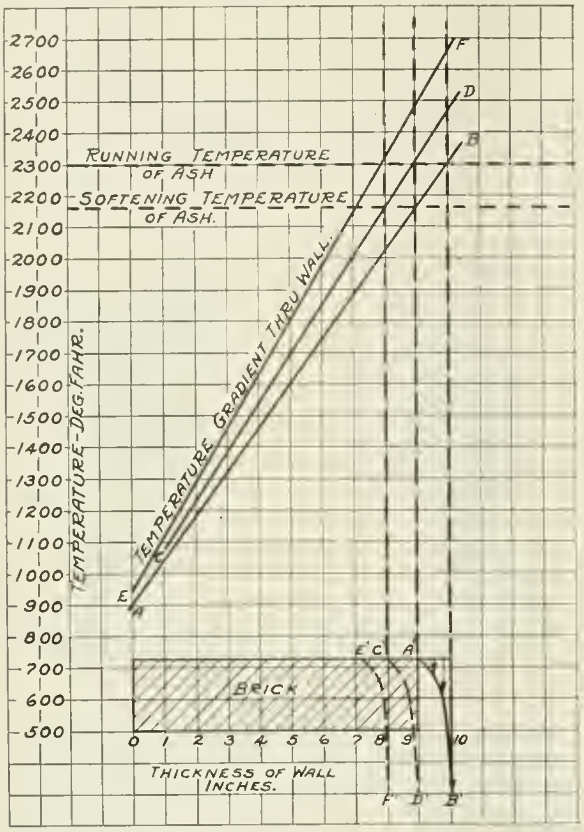

Fig. 4 Manner in Which Erosion of Furnace-Wall Firebrick by Molten Ash Takes Place

Ash erosion is a function of the depth of penetration of the ash-flow temperature into the furnace lining, the porosity of the wall, and the relative composition of the refractory and the ash with which it comes in contact. The manner in which this erosion takes place is well illustrated in Fig. 4, for which diagram and the explanation following the author is indebted to an article by Henry Kreisinger in the 1922 Prime Movers Committee report.

If the surface of the furnace lining is below the running temperature of the ash, the molten ash coming in contact with it is cooled to the temperature of the brick and becomes a thick, viscous fluid adhering to the brick and moving slowly over the surface. Owing to its high viscosity the ash does not penetrate into the brick and will not wash it away, but forms a pasty coating over the surface of the brick. The thickness of this coating depends on the interval between the softening temperature and the running temperature of the ash, and on the rate at which heat passes through the layer of pasty ash and the brick. The surface of the coating away from the brick is at the running temperature, and any further deposit of molten ash will run down over the coating without harming the brick. This condition is shown in Fig. 4 by the temperature gradient *AB*. The length of the arrows near the surface of the brick indicates the speed at which the various layers of the coating of the ash move. The heads of the arrows form a curve *A'B'*.

If the surface of the brick is at the temperature of the running ash, the ash penetrates to a small extent into the brick and the abrasion of the furnace lining begins. This condition is illustrated by the temperature gradient *CD*. The curve of the moving slag is shown by the dotted line *C'D'*.

A temperature condition very destructive to the brick lining is shown by the gradient *EF*. The temperature of the running ash is one inch within the brick and the molten ash penetrates into the brick rapidly and washes the brick away.

The depth of penetration of dangerous temperature in furnace walls with a given furnace temperature is largely influenced by the material of which the wall is constructed, its thickness, and the velocity of air currents against the outside of the wall.

The effect of these items is shown in Fig. 5. In preparing this diagram it was assumed that the furnace was operated in such a manner as to maintain a temperature of 2500 deg. fahr. at the inner edge of the wall; that the coal burned has an ash-softening point of 2100 deg. and the ash flows at 2300 deg. fahr. To the left of the figure are shown various wall thicknesses of solid firebrick. In the center are walls composed of a combination of firebrick and insulating material which is assumed to have one-tenth the heat conductivity of firebrick, and on the right is illustrated the hollow-wall construction, where the air for combustion absorbs the heat radiated through comparatively thin walls. A study of these diagrams shows clearly the danger of using insulation in furnace walls where the walls are not provided with any cooling arrangement, and the advantage which results from employing the hollow ventilated wall construction where high combustion temperatures are being dealt with.

If we would obtain the highest efficiency coupled with long wall life, the walls must be so constructed that air cannot leak into the furnace and a minimum of heat will be radiated from the walls. This must be done while burning the fuel with a mininum of excess air which has been preheated several hundred degrees; and it is obvious that walls made of fireclay brick will not stand such punishment unless some means are provided for reducing the wall temperature relative to the combustion temperature in the furnace.

In the Lopulco system of burning pulverized coal a combination of air and water cooling of furnace walls has worked out very satisfactorily. This system of cooling the walls by heating air for combustion is well suited to conditions where it is desireable to introduce a large part of the air for combustion as secondary air, but would not be very desirable in combustion systems where all or a large part of the air is primary air, such as stokers, mechanical atomizer oil burners, and certain powdered-coal systems. Another difficulty with air-cooled walls is that it makes it more difficult to use low-level heat which is available at slight expense for preheating combustion air.

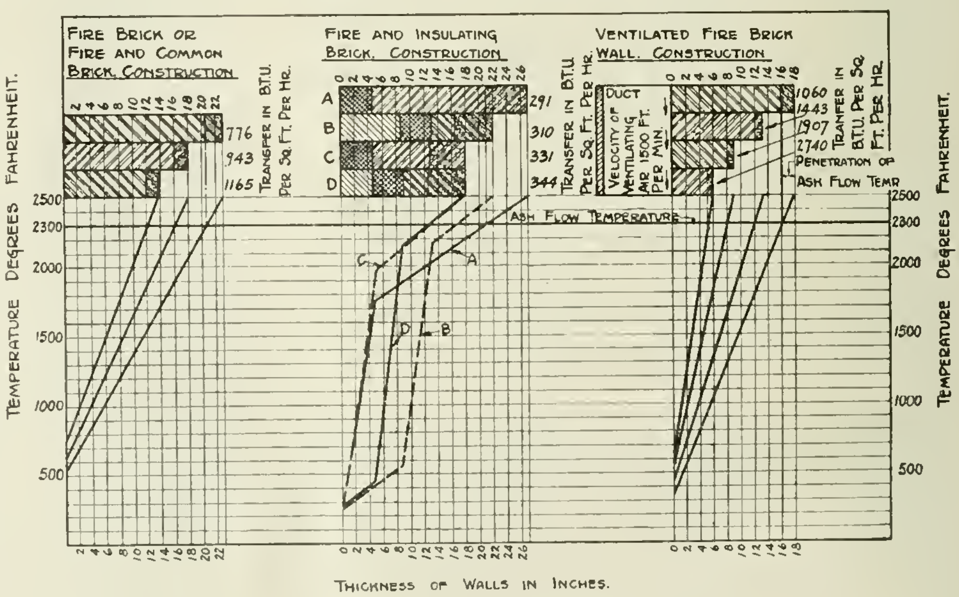

Fig. 5 Effect of Type of Furnace-Wall Construction on Penetration of Dangerous Temperatures into Brickwork

In the author's opinion the present tendency of boiler-furnace design is toward a furnace in which combustion will take place entirely surrounded by water- and steam-cooling surfaces.

Discussion

Mr. Ricketts' paper was presented on March 27 at a meeting of the Metropolitan Section of The American Society of Mechanical Engineers, and for helpful discussion and sustained interest the session was one of the best ever held under the auspices of that section. Kingsley L. Martin, chairman of the Fuels Committee of the Section, presided.

In presenting his paper Mr. Ricketts gave the following additional ratios of cubic feet of furnace volume to rated boiler hp.,

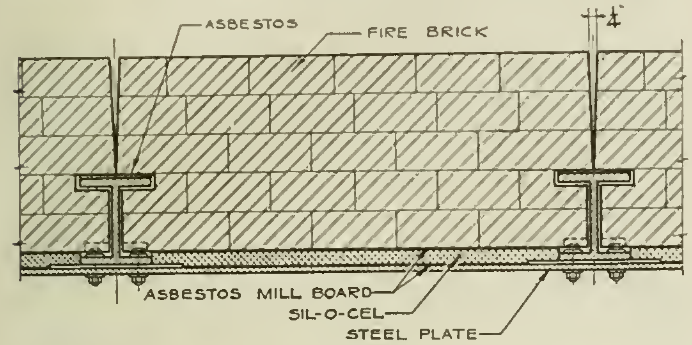

Fig. 1 Plan of Furnace Wall at Hell Gate Station, United Electric Light & Power Co.

(The tapering expansion joint closes when the boiler is in service.)

these representing furnace design of plants built some years ago:

	Cu. ft. per rated boiler hp.
Waterside Station, New York Edison Company	1.05
Essex Station, Public Service of New Jersey	1.95
Dodge Bros., Mishawaka, Ind.	2.17
Muscle Shoals	2.17
Connors Creek, Detroit Edison Co.	2.75
L. Street, Boston	2.93
Springdale Plant, Pennsylvania Power Co.	2.95

The discussion was opened by V. M. Frost[1] who emphasized the desirability from an overall economic standpoint of using ordinary, first-quality brick in furnace construction, rather than the more expensive so-called "super-refractory" brick; also the desirability of obtaining from the brick manufacturers a more uniform product, true to shape and dimensions, which would very materially assist in obtaining better service and longer life from the common refractories.

He also outlined the possibilities of the use of air-cooled walls as a means of securing better service from the ordinary brick, which would stand up better under compression loads if the heat of the furnace did not penetrate too deeply, as indicated in Mr. Ricketts' paper.

In his work Mr. Frost used the ratio of combustion volume to heating surface, and stated that he had found a value of 0.4 to 0.5 to be a satisfactory one for this ratio. In a furnace designed on this basis under a boiler of 3000 sq. ft. of heating surface, over 2000 lb. of coal per hour had been burned, without slagging or melting of the brick.

John H. Lawrence[2] presented a sketch, Fig. 1, showing the method of constructing the walls of the Hell Gate Station by which the strain on the wall was reduced and expansion provided for. Mr. Lawrence pointed out that a particular trouble in brickwork maintenance was caused by erosion of the front wall just above the stoker.

E. S. Cooley[3] told of the recent realization on the part of paper manufacturers of the importance of fuel saving. The steam plant of the paper mill must furnish steam at 90 lb. to cook the wood and at 15 lb. pressure to dry paper. In a large paper mill there was a remarkable opportunity for economy in fuel. In the design of furnaces Mr. Cooley emphasized the importance of making proper allowances for expansion and contraction. He had successfully used an expansion joint of asbestos millboard. He also told of his experience in installing oil burners under low-set boilers and of securing high efficiencies by allowing the entire lower sets of tubes to be exposed to the flame.

C. G. Spencer[4] commented on Fig. 1 of Mr. Ricketts' paper and stated that in considering the ratio of furnace capacity to boiler horsepower the characteristics of the fuel must be kept clearly in mind. At the Cahokia plant, which had the large ratio of 6.05 cu. ft. per rated hp., the coal used had a long flame of from 50 to 60 ft., the temperature of the ash was 2000 deg. fahr., and the coal had a sulphur content of 5 per cent and an iron content of 18 per cent. Mr. Spencer also stated that it was his belief that an air-cooled wall would give the longest life. He described an economical method of repairing side walls in which a ganister of refractory material was applied with a cement gun.

A. W. Patterson[5] discussed a number of drawings which he had

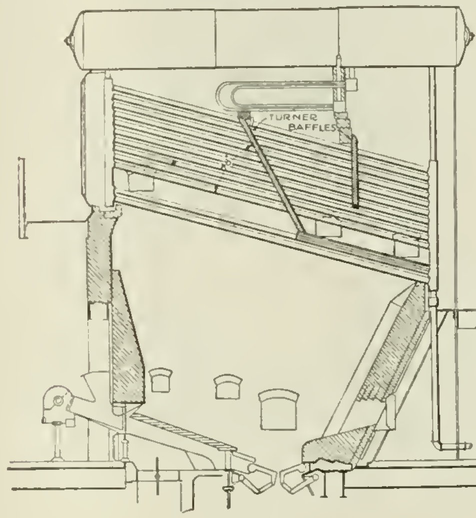

Fig. 2

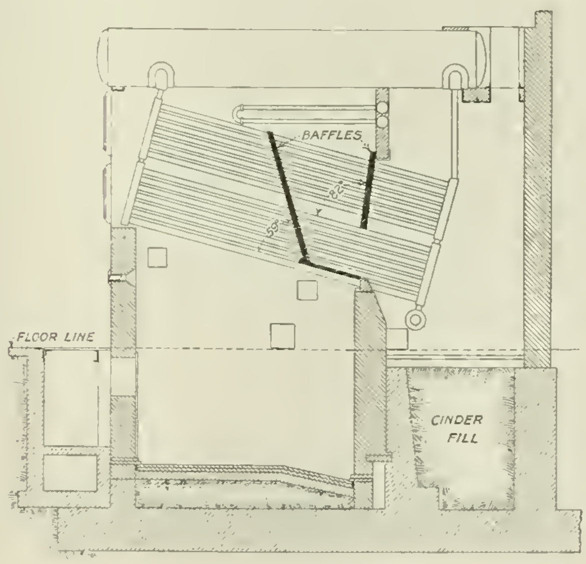

Fig. 3

projected on the screen and which were taken from existing installations, the purpose being to illustrate the possibilities of harmonizing baffle and furnace design to secure long life for the furnace and low maintenance costs. In the first, a vertical baffle, the bottom of which was connected with the bridge wall by means of a flat shelf, was replaced by an inclined one similar to that shown in Fig. 4, with the lower end resting on the bridge wall. In the second the baffling was arranged roughly like that of Fig. 2. In both cases the baffle was laid out on the principle of exposing additional heating surface to the radiant heat of the furnace, thereby lowering somewhat the furnace temperature and absorbing heat

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[4] Mechanical Engineer, McClellan & Junkersfeld, New York, N. Y. Mem. A.S.M.E.

[5] Vice-Pres., The Engineer Co., New York, N. Y. Mem. A.S.M.E.

which would otherwise have to be taken up by the brickwork. Also the lower velocities due to increased opening in the entrance to the first pass decreased the possibilities of slag and a tendency toward positive pressure in the furnace.

The setting shown in Fig. 2 was used on eight 1000-hp. and six 750-hp. boilers with underfeed stokers. The bridge wall and back wall were one with a backward slope. This gave rigidity and a reflecting surface throwing the heat out of the furnace against the tubes. The front wall was built in two separate parts, one under

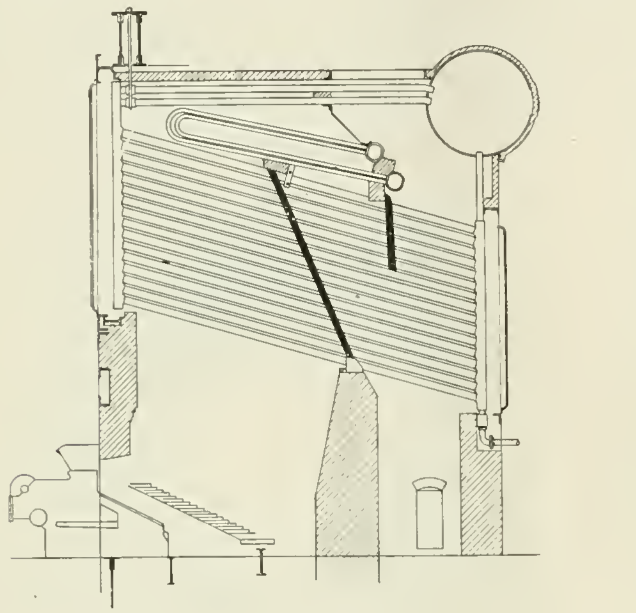


Fig. 4

the header and the other from the stoker up. This relieved the brickwork of weight and the backward slope of the protecting wall added to rigidity. The entire roof of the furnace was heat-absorbing; the entering velocity in the first pass was low. These boilers had been in operation for a number of years with excellent operating efficiency and low maintenance.

Fig. 3 showed the solution of a furnace problem for low-set boilers in connection with the application of oil burning. The higher ratings made necessary a considerable furnace volume; also height and depth. It was learned that the foundations were in excellent condition and were so built that the furnaces could be installed in the foundations. This was done by the proper use of insulating materials combined with firebrick. It was noted that the bridge wall was supported by a concrete pier. The sidewalls had protecting piers of insulating material and firebrick. The baffle design was made to conform to the furnace by a combination of a flat shelf and inclined front baffle, the design being such that a suitable soot pocket could be secured behind the bridge wall.

The boiler shown in Fig. 4 had a builder's rating of 1500 hp. and was installed in the Middle West. A considerable amount of slagging in the lower rows of tubes occurred due to the character of coal available. This slag caused a tendency toward positive pressure in the furnace and trouble was experienced in maintaining the front wall. The baffles were accordingly redesigned as shown in Fig. 4, increasing the entrance to the first pass about 50 per cent and changing the rear baffle to prevent restriction of gases in passing through; a slight backward corbeling was also given to the bridge wall to provide rigidity of the bridge wall and to conform to the new baffle location. Originally the front baffle was vertical, dropping from the top point of the present inclined baffle. At its lower end the old baffle was connected by a baffle following the tubes to the vertical bridge wall which occupied nearly the position of the present one.

These changes, which reduced the velocity of the gas entering the first pass, and possibly the somewhat lower furnace temperature, entirely eliminated slagging, which in turn prevented the occurrence of positive pressure and materially increased the life of the brickwork. It was also found that the stoker repairs were somewhat reduced and that possibly a somewhat lower flue-gas temperature resulted. During the past twelve months (the second year's operation), this boiler was on the line 86 per cent of the time as compared with about 70 per cent average time of the other boilers in this plant. The total cost of maintenance of boiler, furnace and stokers was about one-third the average for about five other boilers in the plant.

Other drawings shown by Mr. Patterson were front and side elevations of a 1000-hp. boiler, in the brickwork of which the use of molded blocks was carried out quite completely, the blocks being 6 by 6 by 18 in. The jointing was reduced about 30 per cent as compared with ordinary firebrick, and the larger size, it was thought, formed a better bond with the outside walls. The furnaces were made with an air space and cast-iron ties were inserted to form an additional bond between the inside and outside sections of the wall. The side walls were supported with relieving arches. The front wall under the header was of the suspended-arch type. Perforated blocks were used along the clinker line of the bridge wall.

The boilers shown in Fig. 5 were of approximately 1600 hp. each. The original baffling arrangement was such that positive pressure occurred and there was considerable brickwork maintenance. The baffles were redesigned, securing lower velocities at the entrance to the first pass and a lower draft drop through the entire furnace. This change eliminated the slag and positive-

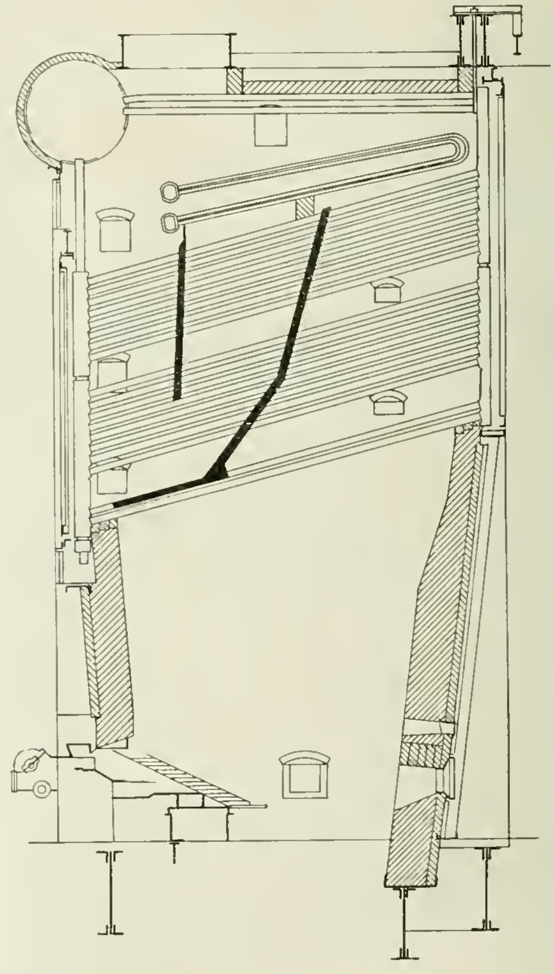


Fig. 5

pressure condition and reduced brickwork maintenance. It was interesting to note the funnel shape of furnace, both front and rear walls being inclined, giving additional rigidity.

The principles involved were the same for boilers operating with powdered coal.

Other discussions were submitted by George Bell, T. B. Stillman, H. D. Savage, E. Wise Sayer, and A. A. Adler. The last mentioned pointed to the excellent results attained in Scotch marine and locomotive boilers where the firebox is surrounded by heating surfaces.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

The Generation and Utilization of Cold

A GENERAL discussion on the generation and utilization of cold was held jointly by the Faraday Society and the British Cold Storage and Ice Association on October 16, 1922. The subject was treated under two headings, namely, laboratory and industrial methods of liquefaction, and practical applications of low temperatures. The subjects discussed belong particularly to the region of low temperatures such as are involved in the liquefaction of gases rather than that of medium temperatures as used in ice making and the like.

Prof. J. Kamerlingh Onnes of the Leyden cryogenic laboratory spoke of the lowest temperature yet attained. He gave a brief history of the efforts made in the liquefaction of helium, together with a description of apparatus employed. In this work, it may be mentioned, he was assisted by a gift of helium from the United States Navy. With the apparatus recently developed considerable amounts of liquid helium can be obtained and the author describes in full the apparatus and precautions used. With this it is believed that the lowest temperature obtained is below 0.9 deg. K., and the question whether it would be possible to descend below 1 deg. K. is thus answered positively. If it had been possible to have gone further only one-sixth of a degree, the limit obtainable in the ordinary way with helium would have been reached.

The apparatus and methods in the Leyden cryogenic laboratory are described in a paper with this title by C. A. Crommelin. The purpose of the laboratory is and has always been to be able to produce any temperature below 0 deg. in order to be able to make accurate physical measurements at these temperatures. And the claim is, for accurate measurements at least, a constancy of 0.01 deg. during several hours. The best way to fulfil this claim is to make use of liquefied gases boiling, well stirred, under different pressures and keeping these pressures exactly constant. In Leyden only pressures of one atmosphere and lower (often as low as a few millimeters, and in the case of helium a few tenths of a millimeter) are used, as the construction of cryostats for considerably higher pressures than one atmosphere is difficult and may even present danger. The region of temperatures covered by each substance is therefore the region between the boiling point and its triple point.

The article describes in some detail the liquefaction of air, the hydrogen plant, the liquefaction of helium, the liquefaction and purification of neon, and the various cryostats used at the laboratory.

Prof. C. F. Jenkin presented a paper on ethyl chloride, containing among other things a pressure-temperature curve, and stated that he is carrying out a complete investigation of the thermal properties of this fluid and that complete θ-ϕ and I-ϕ charts will shortly be published.

In the discussion which followed Prof. A. W. Porter suggested a new method for obtaining a truer extrapolation in determining the extremely low temperatures, using for this purpose one of the various theoretical curves which are adopted for representing vapor pressures.

The next group of papers dealt with industrial methods of liquefaction and practical applications of low temperatures. This group started with a semi-historical paper by K. S. Murray on industrial methods of liquefaction, dealing largely with the history of the British Oxygen Company. It also described the features of the Claude and the Linde processes, and referred briefly to the Norton process.

The manufacture of hydrogen by the partial liquefaction of water gas and coke-oven gas was described by Georges Claude. In this process water gas compressed to a suitable degree is in the first instance deprived of its carbon dioxide and moisture. It is then sent into a heat exchanger in which it is cooled by circulating in the opposite direction to the hydrogen and carbon monoxide which have already been separated. The gas then enters the bottom of a sheaf of vertical tubes, the lower portion of which plunges into a bath of carbon monoxide boiling under atmospheric pressure. By the combined influence of the pressure and of the temperature of the liquid bath a large portion of the carbon monoxide of the ascending gases is liquefied and flows back into a collector located below the vertical tubes. This liquid is forced into a vaporizer where it replaces the liquid which is being evaporated. The remaining gas containing hydrogen and a little of the residual carbon monoxide continues to rise in the sheaf of vertical tubes, where it encounters a temperature which is being more and more lowered by special means. Under that influence the remainder of the carbon monoxide is liquefied and the hydrogen, which theoretically ought to be sensibly pure, escapes.

In working this process two sources of inconvenience were encountered. In the first instance when the hydrogen is entering the expansion engine at extremely low temperature the frigorific efficiency of the expansion is very low, in addition to which there is an abnormal friction in the engine which still further lowers the frigorific efficiency. In the second place, the calorific mass of the gases leaving the tubes and circulating about the rising gases is smaller than the mass of the latter by the entire amount of the carbon monoxide which has been liquefied by their action. As a consequence, the ascending gas cannot, even assuming a perfect heat exchange to take place, leave the sheaf of tubes at the temperature at which the expanded gases enter the tube. The author describes how these and other troubles have been overcome in practice. The process has been developed and put into practice in a plant at Grande Paroisse, France, where an apparatus for the production of 500 cu. m. of hydrogen per hour is in operation, feeding a unit for five tons of ammonia per day.

The author mentions also that he has already successfully tried an apparatus where hydrogen is produced from coke-oven gas, which is of importance because it permits the recovery of by-products which are lost now.

Edgar A. Griffiths discusses in detail the production of liquid oxygen for use on aircraft, in particular for high-altitude flying. Of interest in this same connection is the paper by A. J. Bremner describing the Heylandt liquid-air plant, as this was intended to supply oxygen for use with the "Aerophor" liquid-air self-contained breathing apparatus.

The paper by Cosmo Johns deals with another application of oxygen, namely, that of enriching air supplied to metallurgical furnaces, such as copper-smelting, blast furnaces, open-hearth, bessemer, etc. In this connection the author calls attention to the fact that it is not pure oxygen that is required, as it would be amply sufficient if the oxygen content varied between the range of 20 and 40 per cent. What is required, however, is not pure oxygen in steel bottles but enriched air in hundreds of tons, as the production of one ton of pig iron requires 140,000 cu. ft. of air at normal temperature and pressure.

Attention is also called to the papers, Thermometric Lag with Special Reference to Cold Storage Practice, by Ezer Griffiths and J. H. Awbery, Some Materials of Low Thermal Conductivity, by Ezer Griffiths, and A Note on the Importance of the Study of the Crystal Structure and Properties of Metals at Low Temperatures, by Cosmo Johns.

In the discussion which followed Dr. J. A. Harker called attention to a fact which may be of considerable importance, namely, that in four or five different plants which he had visited, working on the Claude process where expansion engines were in use, he had noticed in almost every instance that the energy recovered was turned into a resistance coil and accomplished no useful purpose,

except possibly that of warming the room. It was never used as it was figured in the textbooks and turned into the line to diminish the power requirements in the way that theoretical people talk about.

H. Brier told about an experiment which was made about 1890 with enriched air on a small bessemer converter in Glasgow. Oxygen was then introduced in different percentages into the air blast. At no time was any great quantity of oxygen used, but the results were most disastrous. After a very short time the tuyeres and bottom of the converter were consumed and blew out, and those in attendance very naturally stood away from the converter expecting the charge to follow; but only a moderate flow of liquid came out into the bottom of the pit, and this was found to be the liquid formed by the melting of the tuyeres and lining, all combustible metal having disappeared, leaving only a black skull in the top of the converter.

Cosmo Johns, in dealing with the question of enriched air stated that it was the increase in the partial pressure of the oxygen that was the really significant factor in the use of oxygen-enriched air. The available evidence strongly supported the view that variations in the concentration or partial pressure of the oxygen would alter the order in which the metals and metalloids were oxidized in the bessemer process for basic-steel making.

Dr. Richard Linde, in dealing with the development of the oxygen and nitrogen industries in Germany, gave the following figures: At present more than 2,500,000 cu. m. (nearly 100,000,000 cu. ft.) of oxygen are put upon the German market every month, in steel cylinders. In addition, a large number of engineering works and shipbuilding wharves make their own oxygen for autogenous metal working, and that oxygen production may be estimated at 1,000,000 cu. m. per month. Finally, the chemical industries require very considerable amounts of oxygen which the works likewise generate in their own plants; this oxygen will also exceed 1,000,000 cu. m. per month. Thus Germany is at present producing at least 50,000,000 cu. m. (1,750,000,000 cu. ft.) of oxygen per year.

The amount of nitrogen produced by the liquefaction of air and utilized almost exclusively for the manufacture of fertilizers is considerably larger, Dr. Linde estimating the annual German demand for nitrogen at 300,000,000 cu. m. (more than 10,000,000,000 cu. ft.). (*Transactions of the Faraday Society*, vol. 18, pt. 2, no. 53, Dec., 1922, pp. 139–273, illustrated, *tdA*)

Short Abstracts of the Month

AERONAUTICS (See also Internal-Combustion Engineering)

Marcel Besson H-5 Quadruplane Flying Boat. It is stated that this machine has recently been successfully tried out in France. The problem was to design one that would, without being too cumbersome, be capable of carrying heavy loads and a large number of passengers, as many as twenty. This problem was solved by arranging the planes in quadruple form, one pair close behind the other, and each pair stepped and staggered in relation to the other. Interference between the forward and rear pairs of planes was expected, but the trial flights demonstrated that there was little or none of it.

The main planes are of comparatively thick section and have a high aspect ratio. The upper and third planes are located a little less than the chord width in advance of the second and bottom planes. Each pair of planes has an arrangement of X interplane struts, while struts also connect the rear spars of the forward planes to the front spars of the rear planes. The whole wing cellule is divided into three bays on each side. The arrangement of struts enables the wire bracing to be reduced to a minimum. The lowermost plane is set at a dihedral angle—about $1^1/_2$ deg. Ailerons are fitted to all four planes; these ailerons, it will be seen, are long and narrow, and although their individual effectiveness may be slight, their combined action should give ample control.

One advantage claimed for the grouping of the main planes as adopted by M. Besson is that the travel of the center of pressure for each plane is small, and therefore the total c. p. travel is also small, whereas this would be much greater if only two planes, giving the same combined total area, were employed. Consequently it is said that, for a large machine, this arrangement makes for easier piloting.

The tail group of the Besson quadruplane is also interesting. It consists of two horizontal and three vertical surfaces. Of the former, the upper and smaller is used as an elevator only, while the lower and larger surface (of 26 ft. 3 in. span) serves as a stabilizer and has an auxiliary "elevator" for adjusting the incidence for longitudinal trimming. The three vertical surfaces comprise a central triangular fin, to the trailing edge of which is hinged a rudder and two similar but smaller units mounted one on each side of the central one. The hinged flaps on these outer surfaces are normally in neutral position but may be adjusted at the will of the pilot for the purpose of trimming the machine should the failure or fall in power of one or other of the engines necessitate this.

The engines at present fitted are four 250-hp. Salmsons. During the tests the machine, which weighs fully loaded just over 10 tons, took off a run of some 500 yd. and attained a speed of 81 m.p.h. with full load. (*Flight*, vol. 15, no. 7/738, Feb. 15, 1923, pp. 89–90, 2 figs., *d*)

AIR MACHINERY

Formula for the Rate of Exhaustion of a Large Tank by a Reciprocating Air Pump, E. Buckingham. The conditions for the validity of the formula are as follows: (1) The piston and the valves do not leak; (2) there is no appreciable throttling except at the valves; (3) the volume to be exhausted is very large in comparison with the piston displacement; (4) the temperature of the air in the tank is constant; (5) the temperature in the pump at the end of any suction stroke is constant; (6) the pump discharges to atmospheric pressure, and the air in the tank starts at atmospheric pressure.

Let P = atmospheric pressure
N = number of completed pump cycles
p = pressure in tank after N cycles
x = p/P = degree of exhaustion
l = limiting or lowest attainable value of x
a = fraction of 1 atmosphere required to lift the discharge valve
b = fraction of 1 atmosphere required to lift the intake valve
c = ratio of clearance to piston displacement
t = ratio of absolute temperature in the pump at the end of a suction stroke to absolute temperature in the tank
v = ratio of volume of tank to piston displacement
n = exponent in the equation of the compression line, pv^n = constant

In any one problem the last six quantities are pure numbers and independent of the units used. a, b, and c are always small; if the valves are operated positively, $a = b = 0$; if the pump is oil-sealed, $c = 0$. The temperature ratio t never differs much from unity. The volume ratio v is supposed to be large. The exponent n is between 1.0 and 1.4.

The formulas obtained are:

$$N = A \log_{10} \frac{C}{(x - b)^{1/n} - B}$$

and

$$l = B^n + b$$

where

$$A = \frac{2.303\ ntv}{1 + c}$$

$$B = \frac{c}{1 + c}(1 + a)^{1/n}$$

$$C = (1 - b)^{1/n} - B$$

(Abstract of *Technologic Paper of the Bureau of Standards*, No. 224, *e*)

BUREAU OF MINES (See Corrosion)

BUREAU OF STANDARDS (See Air Machinery)

CORROSION

Corrosion Tests of Metals in Mine Waters. The results of corrosion tests on 45 different metals and alloys in acid mine waters from coal mines, made in the course of a coöperative investigation by the Carnegie Institute of Technology, the United States Bureau of Mines, and an advisory board of coal-mining engineers, are summarized in Bulletin 4 of the Coal-Mining Investigations series, just published by the Carnegie Institute of Technology, Pittsburgh, Pa.

Water from coal mines is usually decidedly acid in character, and causes considerable trouble and expense owing to its corrosive action on mine equipment. These waters contain free sulphuric acid, and ferrous, ferric, and aluminum sulphates, in addition to sulphates of calcium, magnesium, sodium, and potassium, together with silica, and usually some chlorides. On standing, dilution, aeration, or warming, insoluble iron compounds tend to precipitate, principally as hydrous ferric oxides. The occurrence of iron sulphates and free sulphuric acid is due to the action of water and air on the pyrite or marcasite associated with the coal. These substances are oxidized to ferrous sulphate, ferric sulphate, and sulphuric acid.

In the coöperative investigation made by the Bureau of Mines and the Carnegie Institute of Technology three test specimens of each of the 45 metals and alloys were completely immersed in flowing water at each of three coal mines in western Pennsylvania for periods ranging from 98 to 135 days. The waters from these mines covered a wide range of acidity, from one esteemed to be below the average of that region to a water which is considered to be extremely acid. Inspections were made at regular intervals, and the degree and nature of corrosion was noted. At the completion of the test the specimens were removed, cleaned, and the extent and nature of the corrosion recorded. Samples of the mine waters were collected at each inspection, and the degree of acidity determined. Complete analyses were also made on the waters from the three mines.

All alloys tested of the brass type, containing considerable zinc, were corroded extensively by the mine waters. Bronzes, containing considerable tin, were also corroded, but to a less extent than the brasses. Evidently copper-zinc alloys are less desirable for use in mine water than copper-tin alloys.

Cupro-nickel alloys were corroded about to the same amount as the brasses. Nickel-silver alloys, which contain copper, zinc, and nickel, were also corroded extensively. Aluminum alloys showed a marked tendency to pronounced pitting.

The materials which showed a marked resistance to the corrosive action of the acid mine waters include a high-chromium steel, two highly alloyed chromium-nickel-silicon steels, a high-silicon cast iron, and a nickel-chromium-iron alloy. All of these materials, except the high-silicon cast iron, contain large amounts of chromium. These resistant materials have certain disadvantages for general use in coal-mine equipment, such as the brittleness and hardness of the high-silicon cast iron and the relatively high cost of the others; however, these resistant materials should prove satisfactory for use in pump parts and other equipment where these factors are not a serious consideration.

Economic considerations, such as cost, ease of fabrication, and physical properties, will be factors in determining the suitability of a metal or alloy for use in equipment exposed to the action of acid mine water. (Abstract from Bulletin 4 of the *U. S. Bureau of Mines*, by W. A. Selvig and George M. Enos, *ep*)

ENGINEERING MATERIALS (See also Corrosion)

Aluminizing Iron Articles. The following is quoted from the Notes and Memoranda column of a recent issue of *The Engineer*, which does not, however, give the source of the information.

"Articles made of a 15 per cent aluminum-iron alloy develop, on being heated to redness, a thin but highly resistant surface layer of aluminum oxide which does not scale, and prevents further oxidation of the metal, so that no appreciable alteration of the surface is noticeable after heating at a high temperature for one hour in a strongly oxidizing atmosphere. The alloy gives good castings and may, with care, be forged. Similar results are obtained by treating soft-iron articles by the Alitier process, which consists in heating the metal for some time, surrounded by a powder containing aluminum, whereby the latter penetrates the surface of the iron for a certain distance and forms a surface layer of iron-aluminum alloy that behaves in a similar manner to the 15 per cent alloy described above. An iron crucible treated by this method was practically unattacked after heating to 1000 deg. cent. for sixty hours, whereas a similar untreated crucible was destroyed in twenty-four hours." (*The Engineer*, vol. 135, no. 3500, Jan. 26, 1923, p. 93, *g*; cp. the process known in America as "calorizing.")

Condenser Tubes—Manufacture and Specifications

Condenser Tubes, Their Manufacture and Specifications, Technical Staff of the Chase Metal Works, Waterbury, Conn. An interesting description of the general process of manufacture, with special reference to Admiralty brass tubing and including a discussion of the causes of condenser failures.

The authors endorse the change recommended by Committee B-2 of the American Society for Testing Materials, i.e., that the minimum percentage of tin in the Admiralty mixture be decreased from 1 per cent to 0.9 per cent. This change was recommended in order that manufacturers might keep the average tin content as closely as possible to 1 per cent, which seems to be the ideal proportion for this mixture. This the authors feel to be an advantage and recommend the proposed change.

As regards the question of grain size, it is stated that the last drawing and annealing operations determine the final grain size of Admiralty condenser tubes within the usual tolerances.

To prove this statement the following test was made: A tube was picked at random from a pile of tubes that had just received the last but one drawing operation. This tube was cut off, one-half was annealed at a low temperature which gave a fairly small grain size, the other half was annealed at a high temperature which gave a larger grain size. Both these tubes were given the usual final drawing operation and afterward cut into lengths and given different annealing treatments. Although the annealing tests were made with tubes that had widely different grain size to start with, still the final grain size was in no case greater than 0.025 mm. This proves that the last drawing operation and the last anneal are sufficient to control the final grain size of a condenser tube within the usual tolerances.

These and many other tests of a similar nature show (1) that the final drawing and annealing are sufficient to control the final grain size within the usual tolerances, and (2) that the final grain size is absolutely determined by the last two drawing operations and the last two anneals.

This is also the opinion of the U. S. Naval Engineering Experiment Station at Annapolis, Md., which states that, in their experts' opinion, differences of method in the early stages of production, such as the casting process, have no bearing upon the grain size of the finished tube, and that the latter stages of production (drawing and annealing) are the controlling factors.

Entirely separate from the question of the production of such fine grains is the question of their desirability. The authors' search of the technical literature, the results of laboratory experiments, and the examination of failed condenser tubes have disclosed no evidence whatever that a tube of any particular grain size will last longer than a tube of any other particular grain size, other things being equal. It must be clearly understood that grain size is only a measurement of the annealing of temper of a metal. The temper of a finished condenser tube should necessarily fall between certain limits, but by diminishing the size of the grains a point is finally reached where there is a real objection to too fine a grain-size requirement, because in order to produce exceedingly fine grains it is necessary in the final operations to draw the material very hard, preceded preferably by relatively light anneals. This means an increased wear on the dies, an increased tendency toward scratching, and increased difficulty in getting narrow dimensional tolerances. All these things increase the cost of manufacture, for which the user will have to pay and for which he gets no return in increased life of the tube in service.

While a certain range in grain sizes may be desirable, it does not seem advisable to specify a definite size or maximum limits on

grain size and to lay such stress on the necessity of having tubes meet this requirement. This is specially true when it is considered that the determination of grain size in alpha brass is itself a relatively inaccurate measurement where errors of 10 to 20 per cent are common.

The real progress in condenser-tube manufacture has not been in discarding the cast-shell process but in the improvement of that process itself. Within recent years a large amount of research has been done in this connection and great progress has been made in the art of casting shells on a core. At the Chase Metal Works this research has resulted in the development of a special sand core, a special core dressing, and a method of casting by which cast shells are produced absolutely clean and sound. This improvement in the core and core dressing makes a tube as clean on the inside as it is on the outside; in fact, this improved core gives a satin finish and smoothness on the inside surface that the iron mold will not always produce on the outside surface.

In the same way that the grain size of the finished tube is shown to be produced by the last two drawing and annealing operations only, it may be proved that all the physical properties, including the ability to withstand the hammer, pin, and compression test, are likewise determined by the same two operations.

It is obvious from the above that a sound condenser tube can be made to comply with any reasonable specifications, irrespective of its casting or early stages of manufacture, by the annealing and drawing operations.

There are two changes in specifications the authors strongly favor: the inclusion in specifications of a mercurous nitrate immersion test, and decreasing the minimum tin content from 1 per cent to 0.9 per cent. They believe these to be valuable changes and added safeguards to the purchaser, and they do not believe the other changes that have been proposed will result in insuring the purchaser that he will get a better tube or one which will last any longer in service. There are undoubtedly things which future experimentation may bring out to improve the quality and service of condenser tubes. When any such improvements are discovered, the authors' policy dictates that they promptly urge their adoption. (*Raw Material*, vol. 6, no. 3, Mar., 1923, pp. 97–103, illustrated, *gd*)

FOUNDRY

Casting Hubs Entirely in Cores, H. E. Diller. Description of a process in which the core has entirely displaced the mold in the sense that the entire mold is formed of cores without even the use of a flask.

The process refers to casting iron hubs on steel wheels. Because of the lack of space it is impossible to describe in complete detail the whole process. One feature is the use in the mold of an extra cover acting as a pouring core. This pouring core also has holes for the downgate and blow-off, and a strainer is placed in the hole for the downgate. This strainer is used, however, only on hubs which have to be machined.

The cores are made of a mixture of approximately 50 per cent old sand and 50 per cent new sand, bonded with a mixture of pitch binder and a binder produced by the Robeson Process Company, of New York. The original article describes in detail the equipment used for making and baking the cores, and also the somewhat unusual methods in melting the metal and finishing the castings. (*The Foundry*, vol. 51, no. 5, Mar. 1, 1923, pp. 169–175, 12 figs., *dp*)

FUELS AND FIRING

Terminology in Coal Research, Marie C. Stopes and R. V. Wheeler. The authors have been responsible, either severally or jointly, for the introduction of a number of terms into the literature of coal. In the present article they give the definitions of these terms.

Of particular interest are the definitions and discussion of fusain, durain, clarain, and vitrain, these being illustrated by photomicrographs in black and in color.

The article is not suitable for abstracting as it deals chiefly with British coals, but the definitions of the constituents, of course, apply to American coals as well. (*Fuel in Science and Practice*, vol. 2, no. 1, Jan.-Feb., 1923, pp. 5–9, and 1 colored plate, *g*)

HYDRAULICS

Elimination of Water Hammer in Delivery Pipes

Device for Eliminating Water Hammer and Excessive Pressure in Delivery Piping, E. Maynard. The device described (Fig. 1) consists of a cone *A* placed over the delivery pipe. This cone is divergent, of variable length, and of a diameter suitably selected with respect to that of the pipe. It carries a small collar *B* supporting a steel plate *C*, perforated by parallel slots *D*, these slots being separated by bars *E* of triangular section in order that the water flowing may easily subdivide in order to pass over the grate thus formed. The total section of the slots must evidently be at least a little greater than the section of the pipe in order to reduce the loss of head due to the presence of the grate. Over the divergent cone *A* is placed a convergent cone *F* connected with the

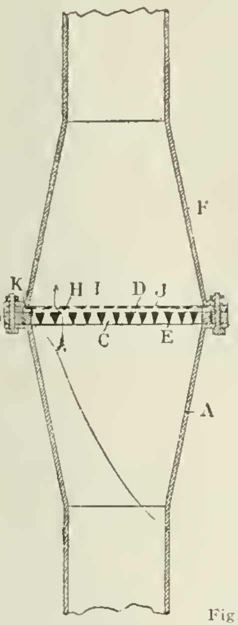


Fig. 1

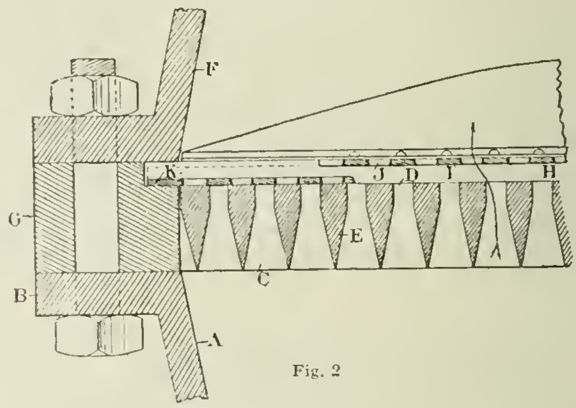


Fig. 2

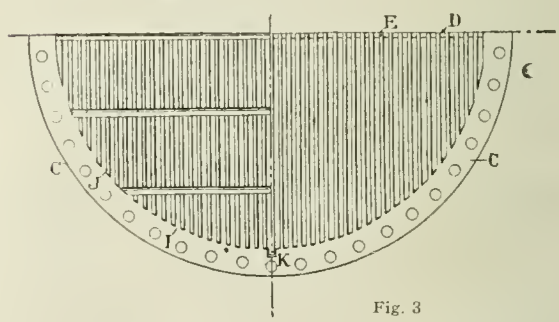


Fig. 3

Figs. 1, 2 and 3 Maynard-Tailleur Device for Eliminating Water Hammer in Delivery Pipes

delivery pipe. There is, however, a free space, say, 15 mm. (0.6 in.), between the upper part of the grate *C* and the bottom ring of the divergent cone. In this space *H* is placed a movable steel plate *I* provided with perforated parallel slots *J*, which do not, however, correspond to the slots in the grate above referred to. This plate can rise from 10 to 12 mm. (0.39 to 0.405 in.), but only under the effect of the pressure of the water produced in the delivery. This movable plate *I* is guided by four posts moving in vertical slots.

Figs. 1 to 3 show this system of grate valves. It is easy to understand how it operates. While the water is being delivered a movable plate which covers the slots in the grate is raised and remains raised in order to provide a passage for the water. When, however, the pumps begin to move slower or stop altogether the velocity of ascension of the water rapidly diminishes, and the plate, the inertia of which is small but which has a certain weight nevertheless, begins to move downward in the liquid and falls to the grate, the slots of which it closes the instant the velocity is reduced to zero, this action being rapid because of the short distance that the descending plate has to travel. As it is possible to regulate

the weight of this plate in a suitable manner so that it will fall to the grate at the precise instant when the velocity of the water is reduced to zero or changes in direction, it becomes possible to obtain a complete elimination of water hammer.

This result is of particular importance as it will make it possible to obtain marked economies in the construction of steel delivery pipe, for it will no longer be necessary to provide excessive strength to take care of water hammer.

The original article contains a numerical description of an application of this method which is patented in France. (*Revue Générale de L'Electricité*, vol. 7, no. 6, Feb. 10, 1923, pp. 211–213, 4 figs., *d*)

Complete Theory of the Centrifugal Pump, L. Bergeron. An extensive article not suitable for abstracting. The author is an instructor in applied hydraulics at the Central School of Arts and Manufactures in Paris and is considered to be one of the best experts on centrifugal pumps in France. (*France-Belgique*, vol. 1, no. 1, Jan., 1923, pp. 16–36, 12 figs., *g*)

INDUSTRIAL MANAGEMENT

Factory Organization. A collection of papers presented at the meetings of four organizations, one of which is The American Society of Mechanical Engineers (meetings of the other three societies being held in Germany).

The conclusion at which the editor, in commenting on these meetings, arrives is that America and Germany are the two countries where most of the work is being done for laying the foundation for the solution of the entire problem of organization.

It is significant that the majority of German papers are devoted not so much to scientific management proper, as it is understood in America, as to the organization of factory and cost accounting. The American Society of Mechanical Engineers papers are presented in detail. (*Werkstatts-Technik*, vol. 17, no. 5, Mar. 1, 1923, pp. 129–159, *g*)

INTERNAL COMBUSTION ENGINEERING

18-Hp. Cherub Aero Engines. Description of a two-cylinder engine developed by the Bristol Aeroplane Company, in particular for use on small aircraft of the glider type.

The engine is a flat twin air-cooled unit with cylinders of an aluminum alloy, with detachable head. The valve mechanism is of interest. A single camshaft with four integral cams, and driven by gearing from the crankshaft, lies inside the crankcase. The cams operate fingers, which, in turn, operate rocking shafts. The rocking shafts are returned by coiled springs and the mechanism is such that when the cylinders warm up there is no increased clearance between the rocking shafts and valves. Twin concentric springs are used for the valves and the whole mechanism is enclosed and automatically lubricated.

Two types of engines have been designed—one with the driving boss running at crankshaft speed to be used in conjunction with the chain-driven propeller, and the other with a two-to-one reduction gear enclosed in the crankcase. The engine has a bore of 85 mm. and stroke 94 mm., develops 18 hp. at 25 r.p.m., and weighs complete 85 lb. (*The Engineer*, vol. 135, no. 3506, Mar. 9, 1923, p. 270, 1 fig., *d*)

New British Lifeboat Motor, W. O. Horsnaill. Description of the motors recently installed in the lifeboats of the Royal National Lifeboat Institution and claimed to be the most reliable gasoline machinery in existence.

The motors are rated at 90 b.hp. at 800 r.p.m. and have six cylinders with a bore of $5^1/_2$ in. and a stroke of 7 in. Not only are they entirely enclosed but all the ports are watertight up to the level of the carburetor inlets, of which there are two and which are carried upward nearly to the top of the engine. To make assurance doubly sure the engine is installed in a watertight case with the control and instrument connections brought through watertight fittings. One of the features of the engine is the combination in one casting of a common tank-type water jacket with a complete crankcase, the latter entirely enclosing the crankshaft.

The two features which deserve particular attention are lubrication and water circulation. As regards the former, it should be borne in mind that automatic and effective lubrication of every moving part is a vital necessity in a lifeboat motor. It is impossible to open the case on a rescue trip and give an extra dose of oil to any part which has run dry. In this case a combination of pressure feed and splash lubrication has been adopted. (The details are given in the original article.)

As regards water circulation, the water circulates in a closed circuit which includes multi-tubular coolers in wells open to the sea, alternative sea connections being provided. The pump draws from either the coolers or the sea, delivering to the center of the tank jacket near the bottom. Thence the water rises through holes to the head and eventually reaches the jacket of an exhaust box which covers the two manifolds. An interesting feature is the grading of the holes to the head to give an equal quantity of water to all parts, according to their distance from the point of supply. From the exhaust box the water may go either overboard or back to the pump suction, the direction being regulated by a thermostat.

The reverse gear is of the epicyclic type with a multiple-plate clutch for the ahead drive. Much trouble has been experienced with reverse gears in lifeboats, hence meticulous care has been taken to guard any possibility of failure. Every part subject to torque is splined to its spindle—this feature including even the control gear—and every internal nut grooved and split-pinned, while outside screws have lock nuts or spring washers. An unusual feature is a locomotive-type shoe brake to hold the pinion gear box for going astern. The control shaft is fitted with a heart-shaped cam which nearly closes the carburetor throttles in the neutral and opens them out for going ahead or astern. A ball thrust block is fitted at the after end of the reverse-gear case, beyond which is a coupling, splined to the shaft and surrounded by a stuffing box to secure watertightness at this point.

A capstan on the fore deck is worked by a clutch in the flywheel. This clutch is fitted with a pinion which meshes with another on a horizontal shaft, the forward end of which drives the capstan through worm gear. By means of hand control gear the clutch is forced into a cone in the flywheel with greater or less pressure according to the pull on the capstan. It will be easily understood that the 90 hp. of the engine would easily break any ropes being hauled or even the capstan gear unless some slipping device was provided. (*Pacific Marine Review*, vol. 20, no. 3, March, 1923, pp. 126–128, 5 figs., *d*)

MACHINE SHOP

Hobbing Tangent-Rack Gears. The Hotchkiss crown-wheel gear was described in Mechanical Engineering, vol. 44, June, 1922, p. 387. The present article illustrates the system used to generate this gearing by means of a conical hob which was devised by H. E. Taylor, chief engineer of the firm. The article describes both the principles of generation of this gear and the machine used. (*Engineering*, vol. 115, no. 2978, Jan. 26, 1923, p. 106, 7 figs., *d*)

MARINE ENGINEERING (See Internal-Combustion Engineering)

METALLURGY

New Method for Case-Hardening. Description of a process developed by Dr. Assar Gronwall, a Swedish scientist, inventor of the Electrometall type of electric shaft ore-smelting furnace. The process is based upon experiments which proved that as the gases enclosed in the case-hardening pots become saturated with carbonic acid, which happens fairly rapidly, the process gradually stops.

The new method consists of converting the carbonic acid as formed to carbon monoxide. This is done by putting catalyzers of a special metal in the form of thin sheets, ribbon, or wires, into the casing box with the carbonaceous matter surrounding material to be case-hardened. The catalyzer then acts in such a way that the carbonic acid, when coming in contact with the metal, passes into carbon monoxide. An iron object may be case-hardened deeper on a certain spot by placing catalyzer there. In the case of gear wheels, they were case-hardened only on the outer parts of the cogs.

The catalyzer is not consumed during the operation and therefore the expense for the new method consists only of the outlay for the original catalyzers and the license to operate.

With this method it is claimed that less carbonizing material is needed, that the temperature can be kept lower than in the usual method, and that the time required is about half that formerly necessary. The tests at the Technical Academy, Stockholm, consisted in treating pieces of steel from the same bar in an electrically heated furnace, first by the usual case-hardening method and second, with the addition of a catalyzer. The amount of case was considerably deeper in the second set of samples, although time occupied, temperature, and other conditions were exactly the same. (*Iron Trade Review*, vol. 72, no. 9, Mar. 1, 1923, p. 660, *d*)

PHYSICS

Glue Bubbles, Carl Barus. The work of Dewar (Journal A.S.M.E., April, 1918, p. 349) and others on soap bubbles have shown that important information can be derived from the behavior of these bodies. The present article deals with glue bubbles, and, in particular, the measurement of pressure increments within the bubble, which the author claims can be done by an interferometer which he has designed.

Glue bubbles can be obtained directly and are sometimes obtained so that they actually last indefinitely; these solid glue bubbles may be ultimately detached. The author discusses the growth of the bubble and shows graphically the result of the successful dilution of the original liquid glue. It would appear that the surface tensions remains low and nearly constant until a dilution of the order of 0.005 is reached, and therefore with further dilution the surface tension increases very rapidly. (*Science*, vol. 57, no. 1466, Feb. 2, 1923, pp. 151–153, 1 fig., *e*)

POWER-PLANT ENGINEERING (See also Engineering Materials)

Some Deductions from Indicator Diagrams, Alberto Keens. Extensive discussion of a practical nature of the indicator diagram and what it teaches. The author has made no special attempt to present anything except a clear practical discussion of his subject, containing such information as would be of use, for example, to a sea-going engineer or an engineer in charge of steam engines; special attention being paid to the salient factors upon which the smooth and economical running of the engine depends.

The paper is not suitable for abstracting but would prove to be of considerable interest to students in engineering and all those who wish to clarify their practical knowledge of the indicator diagram. (*Institute of Marine Engineers*, paper read Jan. 30, 1923, abstracted through advance copy, illustrated by numerous diagrams, *p*)

POWER TRANSMISSION

Mechanical and Electromechanical Oscillations, Henrich Schieferstein. On page 254 of Mechanical Engineering, April, 1923, there appears an abstract describing the general principles of the Schieferstein method of power transmission by oscillations. The present article describes the same subject in greater details and illustrates by drawings and photographs some of the machinery employed. Among other things it mentioned the use of oscillating planes for aircraft. (Abstract of paper read before the Verein deutscher Naturforscher in Leipzig, Sept. 19, 1922, abstracted through *Zeitschrift f. Technische Physik.*, vol. 3, no. 12, 1922, pp. 377–380, 11 figs., *d*)

PUMPS

High-Speed Pump with Ring Valves. This pump, built by the Pulsometer Engineering Company, Reading, England, is of the reciprocating single-acting plunger type fitted with rubber ring valves working on gun-metal seats. The pumps of this type are built in sizes to deliver from 250 to 2000 imperial gallons per hour at heads up to 100 ft. They are designed to run at speeds from 300 to 500 r.p.m., which makes them suitable for belt driving from high-speed electric motors. The pump casing is cast in one piece with the enclosed crank chamber. The front part of the gun-metal plunger acts as a crosshead working on a guide extending into the crank chamber, and thus relieves the plunger and stuffing box from all side strain. The connecting rod is of gun metal with a marine-type large end which works on the pin of a balanced crank.

The suction valves are in the internal grooves and work in compression, while the delivery valves are in the external grooves and work in tension. The aggregate area of the water passages is large, so that the only movement of the valves consists in a very slight compression or elongation of the rubber. The pumps can therefore work at very high speeds with absolute silence under all conditions. (*Engineering*, vol. 115, no. 2981, Feb. 16, 1923, pp. 217, 6 figs., *d*)

Gyroscopic Pumps

Gyroscopic Pumps, Morris Gendrin. In view of the fact that little information is available in English as to these pumps, a somewhat extended abstract of the article is deemed advisable.

In the first place, certain mechanical principles have to be recalled. All movements of an aggregate of material points may be referred to a system of axes arbitrarily movable in space. We have the right to do this, provided we assume that at each of the material

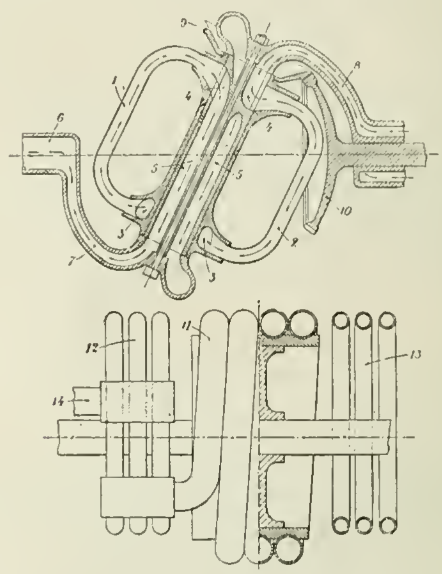
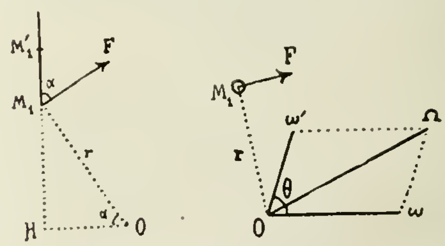


Fig. 4 Diagrammatic Views of Two Types of Gyroscopic Pumps



Figs. 5 and 6 Diagrams of Forces Acting in a Gyroscopic Pump

points M two apparent forces are applied, namely, the inertia of entrainment and the component centrifugal force.

The force of inertia of entrainment is the product of the mass times acceleration of entrainment with the sign changed, the acceleration of entrainment itself being the acceleration of a point referred to movable axes which coincide with the point M at the instant under consideration.

The component centrifugal force is the product of the mass by the complementary acceleration with the sign reversed. If, beginning with the instantaneous axes of the rotation of entrainment, the vector OV be equal to the relative velocity of the point M, the complementary acceleration is equal to twice the velocity which the point V would have under the action of the instantaneous rotation of entrainment. A rotation is often represented by a vector OA projected on the axis and equal to the angular velocity. If the axis

is fixed and the movement uniform, the force of inertia is merely a centrifugal force as generally known.

Assume now, however, that either the direction or the magnitude of the vector OA varies, the point O remaining fixed, which means that A has a certain velocity AB; also take $O\beta'$ equal to AB. It can then be shown that the acceleration is equal to the magnitude which it would have if OA were fixed, plus a component equal to the velocity which would be impressed on the point M by a rotation $O\beta'$. Whereas the centrifugal force tends to draw away from the axis all the material points, the second component tends to make them rotate all in one direction and it is this force that is used in gyroscopic pumps by their inventor, Emil Faure.

Principle of Gyroscopic Pumps. A movable part consists of an aggregate of passages, and for purposes of discussion it is convenient to consider the axes referred to these passages. Under these conditions there occur a certain number of forces producing a displacement of the fluid. These forces may be considered here in succession: first, external forces, in this case gravity; next, the difference of pressures between two adjoining sections of the same passage; third, the action of walls perpendicular to the velocity (owing to a proper selection of the axes) which, however, does not affect the movement of the fluid in the passage. The same definition applies to the component centrifugal force. Next comes the ordinary centrifugal force as used in centrifugal pumps; this is produced by a potential. In gyroscopic pumps, however, there are only two groups of forces that come into action, namely, the pressures and the components due to variations of the velocity of rotation. In other words, an effort is made to obtain a difference of pressure by constantly varying the instantaneous velocity of rotation. Two extreme types have been considered by Faure: in one the direction of rotation alone varies; in the other the magnitude of rotation alone varies (for example, oscillating rotation).

First Type—Description. A certain number of passages 1 and 2 (Fig. 4) mounted two by two in series inside of the curved body 3, constitute the inlet to the pump. Their free ends communicate with the cylindrical valve 4 forming part of the central tube 5. The motor drives the hollow shaft 6 and this governs the rotation of the conduits 7, 5, and 8 which are connected to the valve. The gear connected to the inductor meshes with gear 10 which is stationary, and thereby gives the inductor a second movement about the relative axis formed by the central tube 5.

The cylindrical valve 4 is so arranged as always to give to the fluid circuit the shape shown by the figure. At the same time the bisector planes of the two orifices of the valve form a certain angle with the plane of the axes of rotation, the purpose of this being to reduce for a certain output the losses of kinetic energy due to impact of the fluid against the walls of the valve. (This arrangement is somewhat similar in principle to the shifting of the brushes of electrical machines.) The pressure may be adjusted to any value below the maximum, and this without changing the velocity, by regulating the position of the valve by rotating it about its axis.

Operation. Assume that an observer standing on the right-hand side sees the shaft 6 rotating in the direction of the hands of a clock. An observer standing above the machine will see the indicator turn in the same direction. The two rotations, of entrainment and relative, are represented by the vectors ω and ω' and they combine into an instantaneous rotation Ω. The extreme end of the vector Ω driven by the rotation ω has a velocity $\omega\omega'\sin\theta$ perpendicular to the plane of the figure and away from the observer. In accordance with the theoretical considerations set forth above, a material point M projecting into M_1 is acted on by a force $F = m\omega\omega'r \sin \theta = Kr$ (Fig. 6). This explains why the liquid in Fig. 4 follows the path indicated by the arrows. With this in mind it is very easy to carry out the calculations. Here merely the result will be given. The work which a force F exerts in producing a displacement $M_1M'_1$ of a point M_1 is equal to—

$$M_1M'_1 + Kr \cos \alpha = K \times M_1M'_1 \times OH = 2K \times \text{area } OM_1M'_1 \quad (a)$$

As a result the work applied to a mass m of a liquid is equal to $W = 2m\omega\omega' \sin \theta S$, where S is the projection of area of the circuit on the plane of the figure. If V is the volume of this liquid mass having a density ρ, then $W = V(p - p_0)$, and consequently $p - p_0 = 25\omega\omega'\sin\theta S$. If the liquid flows through a circuit the sectional area of which is 1 sq. dm. and the two shafts (perpendicular) make 10 r.p.s., the pressure will be 0.8 kg. or 8 m. of water, which shows that it is possible to obtain considerable pressures without making the velocity excessively high.

The second type of pump, shown in the lower half of Fig. 4, namely, one where the velocity of rotation alone varies, is also described in the original article, but cannot be discussed here owing to lack of space. (*France-Belgique*, vol. 1, no. 1, Jan., 1923, pp. 69–71, 3 figs., *dA*)

RAILROAD ENGINEERING

Willamette Geared Locomotives. Brief description of geared locomotives manufactured for logging purposes by the Willamette Iron and Steel Works, Portland, Ore. The locomotive uses a side drive and is equipped with a three-cylinder vertical engine

Fig. 7 Geared Locomotive Built by the Willamette Iron and Steel Works, Portland, Ore.

capable of developing approximately 900 hp. The boiler carries a working pressure of 200 lb. and is built in accordance with the requirements of the A.S.M.E. Code. The Walschaerts type of valve gear has been adapted. A photograph of the locomotive is reproduced in Fig. 7. (*Railway Age*, vol. 74, no. 16, Mar. 24, 1923, pp. 809, 1 fig., *d*)

New Cars of Special Design for the London Electric Railway. The London Electric Railway Company (Associated Underground Companies) not long ago gave an order for one car each to five leading rolling-stock construction firms, giving them practically permission to build cars to their own designs, in addition to which one car built to the design of the Underground engineering staff was also placed in service.

Among the features introduced may be mentioned the position and width of the doors, which is uniform in all the cars, namely, a pair of double doors spaced along each side of the car. A further feature is the attempt which has been made to provide as silent running a car as possible. Dr. Low, on behalf of the company, has taken photographs of the sound heard in an ordinary underground subway car when in motion and it was found possible to locate the principal causes of noise. Steps were taken to reduce this and the experience thus gained has been utilized in designing the sample cars. The original article gives an internal view of the cars which are extremely unlike anything used in America. The cars are described as being "de luxe."

The ventilation in the cars is so designed that there will be no need to have windows open while traveling. The original article describes the five cars in detail. (*The Railway Gazette*, vol. 38, no. 6, Feb. 9, 1923, pp. 195–199 and 202, 8 figs., *dA*)

Mikado Locomotives vs. Electrification on the D. L. & W. About 40 per cent of the traffic on the Delaware, Lackawanna & Western consists of anthracite coal mined in the vicinity of Scranton. Scranton and the coal mines are located in a valley with heavy grades—about $1^1/_2$ per cent—in both directions, the grade toward the east being considerably longer than the west-bound grade.

In order to equalize the operating capacity of the road plans were drawn for the electrification of some 40 miles of gradients near Scranton, the intention being to furnish electric-locomotive helper and pusher service to the summits for the east- and west-bound traffic. It was found, however, that the cost of the project would be in excess of \$5,000,000, as a result of which the company decided to postpone electrification for the time being and to purchase in-

stead 40 powerful Mikado-type locomotives. This was done and coal trains are now made up and taken through solid from Scranton to the west or to the seaboard. The new Mikado locomotives with the helper service are hauling trains of 2900 tons through from Scranton to the Secaucus yards, near Hoboken.

With these powerful locomotives a larger tender is used, the capacity having been increased from 10,000 gal. of water and 12 tons of coal to 12,000 gal. of water and 14 tons of coal. This increased capacity enables the locomotives under ordinary conditions to take a train to the summit east of Scranton without taking water and to run 130 miles from Scranton to Secaucus yard without taking coal.

The 40 new locomotives are noticeably heavier than those already in service, and in terms of tractive force are the most powerful Mikado locomotives ever constructed. They were designed by the American Locomotive Company to meet the special traffic conditions on the D. L. & W. and were built at the Schenectady works.

The new Mikado locomotives have 10,600 lb. greater tractive effort than those previously used by the same road. An increase in tractive force of the main cylinders was obtained by changing the piston travel from 30 in. to 32 in. and raising the steam pressure from 180 lb. to 200 lb. The weight of the locomotive was also increased with the result that there is now an axle load of 68,000 lb., which would not have been permissible except for the favorable track and bridge conditions prevailing on the Lackawanna. A booster is also installed, in addition to which are used an Elvin mechanical stoker and a Baker valve gear, together with other modern special equipment.

These D. L. & W. Mikado locomotives will naturally be compared with those for the New York Central Lines, one of the most striking designs brought out in 1922 and for which orders were placed for 191 for the various roads comprising that system. The New York Central locomotives weigh 334,000 lb. in working order, have 28-in. by 30-in. cylinders and 63-in. driving wheels. They also are equipped with boosters and have a total rated tractive force of 74,500 lb., or 63,500 lb. without the booster. Other heavy Mikado-type locomotives recently ordered are those for the Central of New Jersey weighing 342,500 lb., having 27-in. by 32-in. cylinders and a rated tractive force of 59,000 lb., and those for the Northern Pacific weighing 337,000 lb., having 28-in. by 30-in. cylinders and a rated tractive force of 57,000 lb. But few Mikado locomotives having a tractive force of over 60,000 lb. have been built. (*Railway Age*, vol. 74, no. 9, March 3, 1923, pp. 511–513, 5 figs., *dc*)

REFRIGERATION

An Oscillating Ammonia Compressor

Oscillating Ammonia Compressor, H. J. Macintire. A description of what is claimed to be a new type of compressor. The action of the machine is as follows: Referring to Fig. 8, the suction gas enters through pipe *A* into the hollow rotor shaft *B*, which has a long slot *D* through which the gas may pass into the compressor cylinders *C* when the rotor has rotated far enough for that purpose. It will be noticed that the rotor makes with the cylinder *E* four compression chambers *C*, which are single-acting. The gas enters when the ports are uncovered and is discharged through disk-type discharge valves into the annular space *F*, from which it passes to the oil-filled chamber *G*. The compressed ammonia

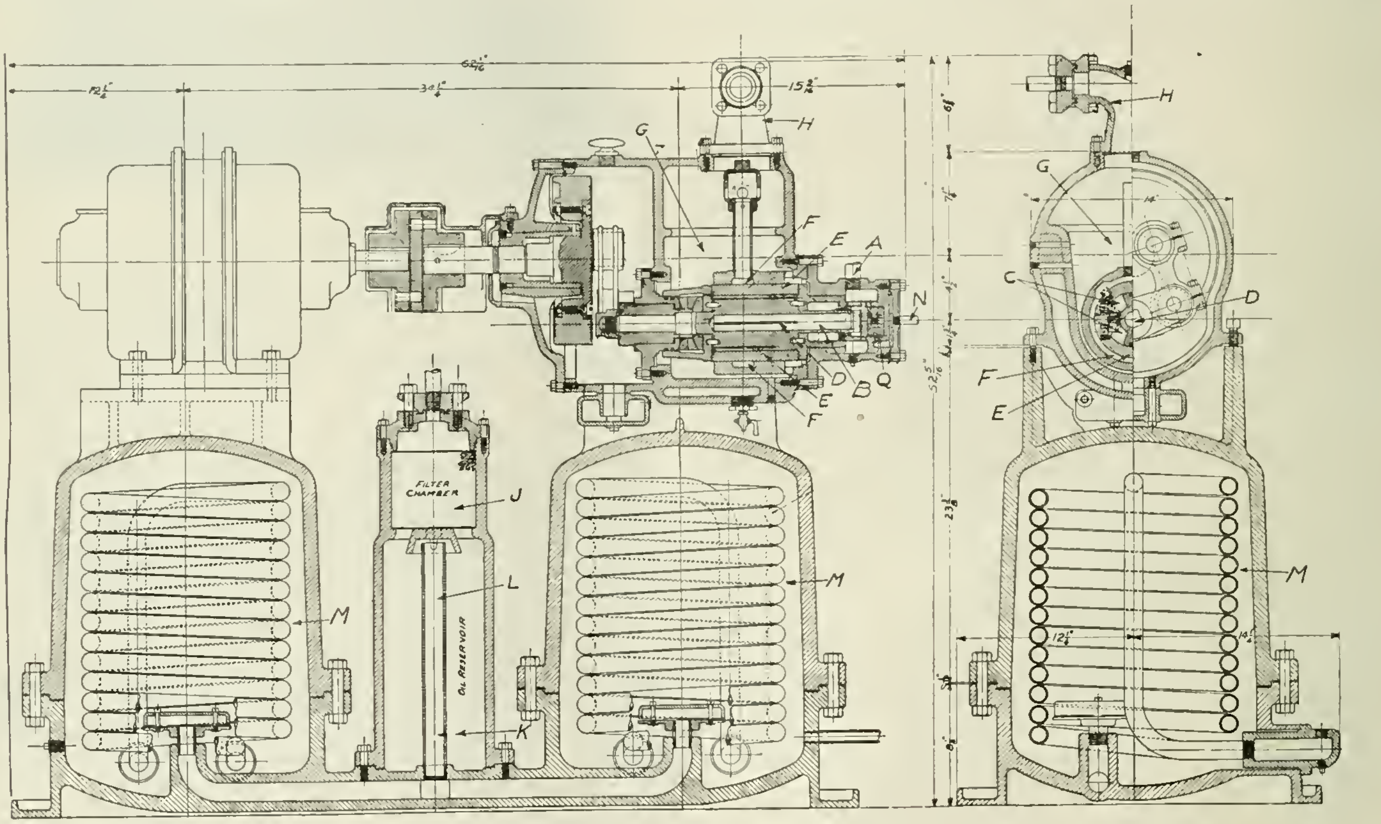


Fig. 8 Oscillating Ammonia Compressor

with entrained oil then passes into the dome *H*. From *H* it is led through a pipe connection to the filter chamber *J*, which is filled with material suitable for the collection of mist particles and the formation of drops. The oil then falls in drops into the oil reservoir *K*, while the ammonia gas is taken through the standpipe *L* into the two shell and coil condensers *M*. The oil from the reservoir *K* is then returned to the compression chamber. It is first led by means of a pipe *M* into the end of the cylinder casing, from which, by means of an oil-measuring device *Q*, it is given passage into the suction gas at *B*.

The rotor is driven by means of a four-bar linkage mechanism, and is designed to rotate through a 69-deg. arc at a speed of 850 oscillations per minute. The compressor is operated practically flooded in oil, reliance being placed on the efficiency of the filter to remove all traces of oil from the ammonia. The ordinary stuffing box is replaced by a self-aligning metal seal *R*. Any oil leaking by this seal will collect in the sump *S*, from which it can be drained occasionally. The shell and coil condensers, in the smaller design, make a convenient frame on which to support the motor and compressor.

It is claimed that the field for such a compressor is in the smaller

designs, especially in view of the noiseless operation of the compressor.

In the discussion which followed, the author in reply to a question stated that he had had but three or four weeks of experience with the device under conditions where gas must leave the cylinder highly impregnated with oil, but the liquid ammonia showed up in the gage glass perfectly clear. (*Refrigerating Engineering*, vol. 9, no. 8, Feb. 1923, pp. 252–253, 2 figs., *d*)

Specific Volume of Saturated Ammonia Vapor, C. S. Cragoe, E. C. McKelvy, and G. F. O'Connor. Data of extensive experiments carried out at the Bureau of Standards some years ago. The paper presents a discussion of previous measurements and data of the present investigation. Among other things, a form of empirical equation expressing specific volume as a function of temperature has been derived.

A form of empirical equation was sought which would represent the results closely and which would also satisfy the terminal conditions at the critical temperature. The equation should, at that temperature, give a finite value for the specific volume u' and approach the value $-\alpha$ for the derivative $\frac{du'}{d\theta}$. In view of the approximate reciprocal relationship between specific volume and vapor pressure, an equation similar to the vapor pressure-temperature equation suggested its possible usefulness with an additional term which would make it satisfy the second condition mentioned above. As in the case with vapor pressure, no simple relation has been found which can be used even over a comparatively small interval of temperature.

An equation of the form—

$$\log u' = A + \frac{B}{\theta} + C \log \theta + D - \sqrt{\theta_c - \theta} + E(\theta_c - \theta)$$

where θ_c is the critical temperature, was found to meet the above requirements.

The measurements were carried out by two methods, one involving a direct determination of the mass of vapor contained in a known volume, and the other an optical method involving measurements of the index of refraction of the vapor, from which the density of the vapor could be determined. The values for the specific heat were calculated from the Clapeyron equation, using other data obtained at the Bureau. The experimental results found by the two methods are in fair agreement with the calculated values above 0 deg. cent., differing at most by about 0.3 per cent. Below 0 deg. cent. the results found by the direct method are systematically lower and those found by the optical method are systematically higher than the Clapeyron values, amounting to about 2 per cent at — 50 deg. cent. The calculated values were chosen, therefore, as the most probable values. The possible sources of error in the two methods are discussed.

The final results are represented closely by the empirical equation:

$$\log_{10} u' = 300\left[\frac{6.46344}{\theta} - 0.106887 + 0.0356803 \log_{10}\theta\right]$$
$$+ 0.0862366\ \sqrt{406.1 - \theta}\ +\ 0.002667\ \ (406.1 - \theta)$$

in which u' is expressed in cubic centimeters per gram and θ in degrees absolute (deg. abs. = deg. cent. + 273.1). (*Refrigerating Engineering*, vol. 9, no. 8, Feb., 1923, pp. 239–248 and 258, bibliography, 4 figs., *e*)

SPECIAL PROCESSES

Forging Steel Tubing Instead of Drawing It, Chester Warner. Description of a process developed by the author in collaboration with E. Warner. It is claimed that by this process large square, round and other internal sections can be made in wall thicknesses of $^3/_4$ in. and up, and in lengths up to 8 ft.

In this process a block of steel of the required weight is pierced with a hole $^1/_4$ to $^1/_2$ in. larger than the size it is to be at the finish. It is carefully inspected and then reheated and placed under a high-speed hammer, where the roughing mandrel is inserted and the block roughed out to the length of the tool, after which the tool is withdrawn and the tube reheated. This last is done very slowly to insure uniform temperature throughout the entire tube. The tube is then again taken to the hammer, the finished mandrel inserted, and the tube drawn to size. Water is employed in this operation as a cooler. If the tube sticks it is only necessary to allow tube and tool to cool, after which the tube may be withdrawn with ease.

It is stated that in no operation has the waste exceeded 10 per cent, and that the ends have been found free from cracks when as little as $^3/_8$ in. has been cut off from them.

Difficulty was at first experienced with the steel used in the mandrels which must withstand severe use. They must not only retain hardness under high temperatures but also keep a smooth, clean surface—not crack or warp. These qualifications have not yet been fully attained, but progress has been made; the mandrels, however, will crack once in a while. The tubes have a slight taper, the dimensions of which for the various sizes are not given. (*Raw Material*, vol. 6, no. 3, Mar., 1923, pp. 90–91, 5 figs., *d*)

STEAM ENGINEERING (See Thermodynamics)

THERMODYNAMICS

Internal-Combustion Heat Losses and Specific Heat of Working Fluid. A somewhat general discussion from which only certain points can be abstracted on account of lack of space.

It is frequently stated that the gaseous medium of closed-vessel tests is highly transparent to its own radiation. The writer questions this assumption for two main reasons, the first being that the diathermancy of the gases will decrease with increasing density. This explains the apparently lower values of specific heat at the higher densities. The reason for the relatively high explosion pressures attained by Professor Petavel in his experiments thus lies in the diminished radiation losses at high densities. In the case of any gases consisting of particles of H_2O the interception of radiated heat by such particles must, at least, be appreciable. Indeed, the fact that the specific heats at constant pressure and constant volume may be written

$$\left(\frac{dK_p}{dP}\right)_T = -T\left(\frac{d^2V}{dT^2}\right)_p$$

and

$$\left(\frac{dK_v}{dV}\right)_T = T\left(\frac{d^2P}{dT^2}\right)_v$$

respectively, is a strong argument against any variation of specific heat with density at high temperatures, since the departure from the usual gas law at such temperatures can scarcely be to the extent required to make the argument valid.

The second reason for non-belief in the high transparency of the gases to their own radiated heat is based on the conviction that during the first half-second of the explosion at least, heat losses in closed-vessel tests are almost wholly radiation losses. This conviction is upheld principally by the fact that test results on explosion vessels of different dimensions can be thereby reconciled. For high transparency, total heat losses on this view, should, in explosion-vessel tests, be proportional to l^3. Actually they are not so proportional. Various figures put forward by different experimenters for the value of the index n in the relation

$$\text{Total heat losses} \propto l^n$$

all agree that n is less than 3. If heat losses in such closed-vessel tests are practically all radiation loss at the outset, as the writer contends, high transparency would give the l^3 law. The only possible argument will be proportional to l^2, and so, in effect, will reduce the index n to some value between 3 and 2.

The author proceeds to show from both experimental and analytical evidence that this reduction in the value of n may be explained by relatively low discrepancy of gases to radiated heat, while holding at the same time that the initial conduction loss (enclosed-vessel test) is practically negligible.

The author surveys some engine tests for purposes of comparison with explosion-vessel tests and derives the following values of the specific heats at constant pressure and constant volume:

$$K_p = 316 + 0.0623\ T \text{ ft-lb. per lb. per deg. cent.}$$
$$K_v = 220 + 0.0623\ T \text{ ft-lb. per lb. per deg. cent.}$$

He plots the internal-energy lines based on the specific-heat values and compares with them lines derived from various authorities, the results showing large discrepancies between these different values. He points out, however, that his values are practically coincident with the values of the specific heats of carbon dioxide, nitrogen and air as measured by Professor Dixon and others, by measurements of sound velocity in the medium. (*The Engineer*, vol. 115, no 3504, Feb. 23, 1923, pp. 191–192, 3 figs., *tA*)

Fundamental Properties of Water Vapor

Fundamental Properties of Water Vapor, Prof. M. Strauven. An analytical discussion, only part of which can be referred to here. Among other things, the author carries through a careful comparison of the systems of values of Callendar and of Eichelberg, and shows that the difference between the two sets of values may be as high as 1 per cent. It is, however, of greater importance to determine not so much the absolute values of I (total energy) as its variations between two given states (the fall of total heat). In practice, expansions beginning with the state of superheated steam end quite often in saturation, a region for which the expression for I takes the form—

$$I = q + xr + Apv.$$

From this the author proceeds to consider the three cases of adiabatic expansion and shows that the differences in results between the Callendar and Eichelberg equations may be, under certain conditions, as high as 6 per cent, which occurs mainly, however, when the initial and final expansion pressures differ but little from each other. This is due to the fact that the absolute values of I in the Callendar and Eichelberg equations are sensibly equal for the high and the low temperatures, but give different results for the region of intermediate temperatures.

The author considers next the specific heats of superheated steam and comes to the conclusion that the values of C_p (Callendar) at high pressures do not agree with the direct measurements of the Munich tests. On the other hand, however, the Munich tests agree perfectly for the region of low pressures with the values experimentally obtained by Callendar. Callendar defended his values by pointing out that the values of C_p at saturation were obtained in the Knoblauch tests by means of a purely empirical extrapolation of experimentally obtained isobars. This objection was answered, however, when Eichelberg succeeded in working out an equation of state of dry steam instead of the extrapolation formula of C_d obtained from this equation of state, and the Callendar equation may be put in the form of—

$$C_p = C_{p_0} + 0.334 \frac{p}{T^{13/3}}$$

The Thomson-Joule effect is discussed next and it is stated that the divergence between the experimental values of Callendar and the calculated values of Eichelberg is comparatively small, which is noteworthy since the determination of the Thomson-Joule effect by means of a throttling calorimeter is an extremely delicate operation, and, for example, the presence of 1 per cent of moisture in the steam at the entrance to the calorimeter may cause a variation of 10 deg. in the temperature of the steam at the exit. Because of this the agreement between the Callendar and Eichelberg values is all the more interesting.

The properties of dry saturated steam are discussed next. In this connection attention may be called to the discussion of the *I-S* diagram as proposed by Schuele, in particular the discussion as to the values of r from the Munich experiments and the Eichelberg equation. There is a material difference between the two, especially above 180 deg., the Schuele values being usually considerably higher. It is the opinion of the author that the only way to determine the cause of these differences is to carry out new experiments on the heat of vaporization of steam at high temperatures. At the same time he points out that the values adopted by Schuele for the high temperatures lead to the conclusion that in that region the total energy at constant temperature may, under certain conditions, increase with the pressure, but the specific volume of a vapor, the conditions of temperature and pressure being equivalent, is always inferior to that of a perfect gas having the same characteristic constant R, and from this the author deduces that with an increase in pressure and constant temperature the total energy gradually decreases, which is contrary to the conclusion resulting from Schuele's values but is in accordance with the relations of Eichelberg and is proved by the values obtained by Callendar. Since, further, the heat of vaporization r appears in the calculation of the entropy of steam, it would follow that Schuele's *I-S* diagram must give values for high pressures which are materially different from those obtained by Eichelberg, and this difference may be in excess of 2 per cent—and even more under certain conditions.

The conclusion at which the author arrives is that of giving preference to the values derived from the equation of state of Eichelberg. He points out at the same time, however, that this equation has been experimentally proved only for pressures up to 25 atmos. and should have further experimental confirmation before being used for extrapolation to higher pressures. From this point of view it would be desirable to study experimentally at high pressures and high temperatures the Thomson-Joule effect, the heat of vaporization, and the value of the exponent in the adiabatic equation. (*Revue Universelle des Mines*, vol. 16, nos. 4–5, Feb. 15 and Mar. 1, 1923, pp. 289–301 with 1 plate of diagrams, and pp. 363–376 with numerous tables and curves, *tA*)

VARIA

Polytopical Clocks with Time Spiral Showing World Time, R. Hirsch. Description of a world-time clock with rotating face and without hands exhibited in the German Museum at Munich. In this clock a map of the world is printed on the face and the clock is so arranged that once the desired city is found on the map the time in that place can be read off, though, it must be stated, not with ease.

Another type of clock for a similar purpose has hands and a stationary 24-hr. face. The hands are fastened on a map of the world in the places representing the locations of the different towns. The map is, however, of a somewhat unusual type, in that while the meridians appear as usual the latitudinal lines have retained their circular shape, but attain their largest diameter at the south pole instead of at the equator. This clock must turn from right to left corresponding to the rotation of the earth from west to east. It also deviates from the ordinary clocks inasmuch as it must be fitted with a special movement, permitting of one rotation of the hour hands within 24 hr.

A method is also described for converting any ordinary 12-hr. watch or clock into a world-time clock without alteration of the movements or works. To achieve this purpose, besides the normal hour hand for the local time several additional hour hands are provided which are fixed at the proper angular distance from the main hour hand and which turn together with the latter. (*Engineering Progress*, vol. 4, no. 3, Mar., 1923, pp. 51–52, 3 figs., *d*)

Doctor of Engineering "Honoris Causa." The German Association of Technical and Economic Societies has issued a protest against the liberal grants of the degree of honorary doctor of engineering by German technical schools where the reason for granting the degree is not the scientific or technical achievement of the recipient but his willingness to make to the institution of learning contributions in coin of the realm. (In particular is mentioned the case of a member of a Berlin firm manufacturing confectionary who has been granted an honorary degree of doctor of engineering by the Technical High School at Carlsruhe, although apparently his name was entirely unknown in connection with any technical or scientific achievements.) It is claimed that such policy on the part of high German institutions of learning will bring disrespect on them and deprive the honorary degrees of any true value. (*Giesserei Zeitung*, vol. 20, no. 2, Jan. 9, 1923, p. 18, *g*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general, *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Viscosity of Lubricating Oils at High Pressures

Progress Report of Special Research Committee on Lubrication

THE A.S.M.E. Special Research Committee on Lubrication was organized in 1915 to investigate the fundamental problems of lubrication phenomena, and has issued progress reports in 1919 and 1921. These may be consulted for information as to the scope of the work in hand and previous results obtained.[1]

The present report contains a further account of the experimental work at high pressures, which has been continued during the past year by M. D. Hersey at the Massachusetts Institute of Technology. This report covers the measurement of the viscosity of several different lubricating oils at temperatures up to 100 deg. cent. and pressures up to about 50,000 lb. per sq. in.

Essentially the same apparatus previously referred to has been employed, the viscosimeter being of the rolling-ball type due to A. E. Flowers, while the pressure measurements were based on the change of electrical resistance of a suitable manganin coil. This method of pressure measurement was originated by Prof. P. W. Bridgman and has since been satisfactorily used elsewhere. A new pump, specially designed for this work through the kindness of Professor Bridgman, was installed at the beginning of the year.

All the above details naturally require a more voluminous report than can be prepared at this date, as the work is still in progress[2] and improvements are constantly being made. The present report, therefore, is only intended to show the general character of the results which are being secured.

Three fixed oils—lard, sperm, and castor—and three mineral oils—Veedol, Texaco, and Mobiloil A—have thus far been tested. Table 1 gives the approximate relative viscosity of these oils at intervals of 500 kg. per sq. cm. and at different temperatures.[3]

TABLE 1 APPROXIMATE RELATIVE VISCOSITY OF VARIOUS LUBRICATING OILS

Pressure, kg. per sq. cm.	Lard 22 deg. cent.	Lard 100 deg. cent.	Sperm 22 deg. cent.	Sperm 100 deg. cent.	Castor 22 deg. cent.	Castor 100 deg. cent.	Veedol (med.) 22 deg. cent.	Veedol (med.) 100 deg. cent.	Texaco (med.) 24 deg. cent.	Texaco (med.) 100 deg. cent.	Mobiloil A 24 deg. cent.	Mobiloil A 40 deg. cent.	Mobiloil A 100 deg. cent.
0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
500	2.4	1.5	1.9	1.4	1.9	1.3	3.2	1.7	4.0	1.3	5.3	7.8	1.3
1000	4.2	1.9	...	...	3.6	2.2	11.7	3.3	14.7	1.7	28.6	21.2	3.4
1500	9.7	2.3	...	...	...	3.5	...	6.1	...	3.0	...	322.0	8.2
2000	...	3.0	...	...	...	5.2	...	9.9	...	5.3	...	...	64.0
2500	...	4.2	...	...		9.0	...	15.5	...	9.0	...	...	...
3000	...	6.1	...	...	...	...	...	25.4	...	16.0	...	...	...
3500	...	...	...	...	...	...	...	...	...	21.2	...	...	...

Approximate values only are available, as several small corrections remain to be computed, particularly those due to the compressibility of the oils, but it is not thought that the figures quoted are subject to changes greater than 5 per cent.

By "relative viscosity" is meant the ratio of the absolute viscosity at a stated pressure and temperature to the absolute viscosity at atmospheric pressure and that same temperature, e.g., 100 deg. cent.

Thus, the data for lard oil show that at 1000 kg. per sq. cm. (14,200 lb. per sq. in.) and 22 deg. cent. its viscosity is four times as great as at atmospheric pressure and 22 deg. cent.; whereas, by contrast, Texaco at 1000 kg. per sq. cm. and 24 deg. cent. has 14.7 times as much viscosity as it had at atmospheric pressure and 24 deg. cent. and therefore shows a more pronounced pressure effect than lard oil. Again, lard oil maintained at 100 deg. cent. experiences a 1.9 fold increase of viscosity under 1000 kg. per sq. cm., while the corresponding effect for Texaco is only to increase its viscosity 1.7 times.

It is to be noted that our present use of the term "relative viscosity at 100 deg. cent. and 1000 kg. per sq. cm. pressure" means that the viscosity under high pressure is being expressed in terms of the viscosity at atmospheric pressure and 100 deg. cent., *not* in terms of the viscosity at atmospheric pressure and 22 deg. or 24 deg. cent. This seems to be a fair way to compare different lubricants in respect to the influence of pressure upon them, though other methods of correlation are being considered.

Table 2 supplements Table 1 by giving the approximate absolute viscosities of the several oils at different temperatures under atmospheric pressure. Table 1, for example, does not show how much more viscous Texaco at 100 deg. cent. and 1000 kg. per sq. cm. may be than lard at 100 deg. cent. and 1000 kg. per sq. cm. By reference to Table 2, however, it can be deduced that under those conditions Texaco is only 0.7 as viscous as lard, while in like manner it is found that lard oil at 100 deg. cent. and 1000 kg. per sq. cm. is 0.4 as viscous as at 22 deg. cent. and atmospheric pressure.

At moderate temperature all of the oils were found to become exceedingly viscous, or else suddenly plastic, at some fairly definite pressure and hence, practically speaking, to have solidified. These solidifying pressures are recorded in Table 3.

The original observations on which this report is based are about 250 in number, exclusive of check observations, and will later be prepared for publication in the form of curves, showing absolute viscosity as a function of pressure and temperature. The viscosimeter has been calibrated for this purpose with due allowance for variations in the density of the oil, as explained in previous papers.[1]

TABLE 2 ABSOLUTE VISCOSITY OF VARIOUS LUBRICATING OILS AT DIFFERENT TEMPERATURES UNDER ATMOSPHERIC PRESSURE

	Viscosity c.g.s. 22 deg. cent.	Viscosity c.g.s. 100 deg. cent.
Lard	0.67	0.15
Sperm	0.39	..
Castor	7.8	0.23
Veedol	0.97	0.09
Texaco	1.1[1]	0.12
Mobiloil A	2.0[1]	0.10

[1] Viscosity at 24 deg. cent.

TABLE 3 APPARENT SOLIDIFYING PRESSURES OF VARIOUS LUBRICATING OILS

	Temp., deg. cent.	Pressure kg. per sq. cm.	Pressure lb. per sq. in.
Lard	22	1600	22,800
Castor	22	1400	19,900
	100	2900	41,200
Veedol	22	1300	18,500
Texaco	24	1500	21,300
	100	3900	55,500
Mobiloil A	24	1200	17,100
	40	1500+	21,300+
	100	2100	29,800

Acknowledgments for individual assistance are due primarily to H. B. Henrickson of the Bureau of Standards in connection with the earlier development work, and more recently to C. W. Staples, a graduate student at Massachusetts Institute of Technology during 1922 (W. P. I. '19), and Henry Shore, M.I.T., '24. Mr. Staples was largely responsible for the pump development and other mechanical problems, while Mr. Shore gave particular attention to the temperature control and other electrical problems introducing various improvements which will be described later.

ALBERT KINGSBURY, *Chairman*
MAYO D. HERSEY
A. WILMER DUFF
H. C. DICKINSON
A. E. FLOWERS.
Research Committee on Lubrication.

[1] The problem of "oiliness" was discussed in the first report, together with experiments by Albert Kingsbury at high rates of shear, and by M. D. Hersey on viscosity at high pressure. The latter results are available in detail in *Jl. Wash. Acad. Sci.*, vol. 6, pp. 525–530, 1916, while the report itself may be found in MECHANICAL ENGINEERING, vol. 41, June, 1919, p. 537. A second report, issued in December, 1921, may be obtained in pamphlet form from The American Society of Mechanical Engineers, 29 W. 39th Street, New York.

[2] The experiments have been resumed by Mr. Hersey at the Physical Laboratory of the U. S. Bureau of Mines, Pittsburgh, Pa.

[3] The kg. per sq. cm. or "atmosphere" is the unit almost universally found in high-pressure literature: it is about 14.2 lb. per sq. in., so that 1000 kg. per sq. cm. is approximately equivalent to 6.4 tons per sq. in. in the British system.

[1] *Jl. Wash. Acad. Sci.*, vol. 6, pp. 528 and 628, 1916.

ENGINEERING RESEARCH

A Department Conducted by the Research Committee of the A.S.M.E.

Résumé of the Month

A—Research Results

The purpose of this section of Engineering Research is to give the origin of research information which has been completed, to give a résumé of research results with formulas or curves where such may be readily given, and to report results of non-extensive researches which in the opinion of the investigators do not warrant a paper.

Building Materials, Concrete A1-23. Tests of Heavily Reinforced-Concrete Slab-Beams. This paper presents the results of tests of 26 slabs, tested as simple beams, having four types of reinforcement. The slab beams were approximately 4 in. thick and $27^1/_2$ in. wide, and the four types of reinforcement consisted of (*a*) plain round bars laid direct between two supports, (*b*) expanded metal with the long dimensions of the diamonds parallel to the direction of the span, (*c*) plain round bars laid in two bands making 45 deg. with the direction of the span of the beam and 90 deg. with each other, and (*d*) plain round bars laid in one band making 45 deg. with the direction of the span.

The immediate purpose of the tests was to obtain data applicable to the design of slab members in concrete ships, and for this reason the slabs did not represent conventional design. This introduced difficulty in the interpretation of the test data, but several methods of interpreting the tests have led to conclusions which are in agreement with each other as to the general nature of the results.

On the whole the test results show a fair agreement with the analysis based upon the secant method of calculation. Expanded-metal reinforcement distributed the tension cracks in the concrete of the slab beams more uniformly throughout the length of the beam than did reinforcing bars laid direct between supports.

This Technologic Paper of the Bureau of Standards, No. 233, by Willis A. Slater and Fred B. Seely, may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. Price, 15 cents.

Ferrous Alloys A1-23. Effect of Manganese on the Structure of Alloys of the Iron-Carbon System. A third Bureau of Standards Technologic Paper, No. 464, in the series on the Preparation and Properties of Pure Iron Alloys, has just been issued. It was prepared from experimental data collected by Messrs. Henry S. Rawdon and Frederick Sillers, Jr. This paper is concerned with the effect of manganese as a hardening element determined in an extensive series of alloys varying from 0 to 1.6 per cent carbon and 0 to 2 per cent manganese. Address Superintendent of Documents, Government Printing Office, Washington, D. C. Price 10 cents.

Fuel Utilization A4-23. Economic Combustion of Waste or By-Product Fuels. Because of the decreasing supply and increasing cost of high-grade fuels, the efficient utilization of those that are of low grade is becoming a problem of major importance to many industries and to the commercial progress of the nation. The data in this paper, consequently, are published as a contribution to the literature on the conservation of national resources. The term "waste fuel" as used in this paper means any combustible material that is not ordinarily included in the list of commercially marketable fuels.

David Moffat Myers prepared this bulletin which is known as Technical Paper 279 of the Bureau of Mines. Address Superintendent of Documents, Government Printing Office, Washington, D. C. Price 10 cents.

Hydraulics A1-23. Loss of Head in Valves and Pipes. A bulletin just issued by the Engineering Experiment Station of the University of Wisconsin on this important subject was prepared from experimental data gathered by Prof. Charles I. Corp and Roland O. Ruble of the University staff. The bulletin presents the results of 2200 tests on 48 different gate and glove valves. Results of 425 tests to determine pipe friction are also included.

Iron and Steel A4-23. Effect of Manganese on the Structure of Alloys of the Iron-Carbon System. See *Ferrous Alloys A1-23.*

Non-Ferrous Metals A2-23. Preparation of Light Aluminum-Copper Casting Alloys. A very large amount of experimental work on this subject has been conducted for the Bureau of Mines by Robert J. Anderson. His report which has just been received is known as Bureau of Mines Technical Paper 287. The author sums up his findings as follows:

Aluminum-alloy foundries in the United States employ three methods for introducing copper into aluminum in making light aluminum-copper alloys: (1) The use of copper directly; (2) the use of 33:67 copper-aluminum alloy; and (3) the use of 50:50 copper-aluminum alloy. The writer suggests that 60:40 copper-aluminum alloy might be suitable for the purpose. A suitable method for preparing rich alloys on a large scale is described in detail. The various methods used at different foundries have been compared.

This paper of 44 pages includes many micrographs and may be obtained for 10 cents from the Superintendent of Documents, Government Printing Office, Washington, D. C.

Non-Ferrous Metals A3-23. Solder for Aluminum. Most of the metals commonly used in solders, except magnesium, are electropositive to aluminum. They therefore accelerate corrosion in the presence of moisture, and soldered joints of aluminum should be protected by varnish.

Various compositions of zinc-tin and zinc-tin-aluminum solders give the best results. This Circular of Bureau of Standards, No. 78 may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. Price, 5 cents.

Paints, Varnishes and Resins A1-23. Moisture-Resisting Coatings for Wood. See *Forest Products A1-23.*

Paper A1-23. Study of Commercial Dial Micrometers for Measuring the Thickness of Paper. Specifications are given for a standard instrument. From a study of the mechanisms of instruments and the results of this investigation it is felt that two or more types of the mechanisms studied can be used in instruments that will meet the specifications. The paper also contains specifications for a standard procedure to determine the mean thickness of a sample of paper.

The Bureau of Standards Technologic Paper No. 226 was prepared by Messrs. P. L. Houston and D. R. Miller and may be secured from the Superintendent of Documents, Government Printing Office, Washington, D. C. Price 10 cents.

Petroleum and Allied Substances A1-23. Oil Shale—An Historical, Technical and Economical Study. In January, 1920, the State of Colorado and the U. S. Bureau of Mines entered into a coöperative agreement for the conduct of laboratory investigations on the oil shales of Colorado. Under this agreement a laboratory has been installed and equipped at the State University, Boulder, Colorado, and a research staff organized. It is the primary purpose of the investigational work to determine the most favorable conditions of retorting Colorado oil shales to yield the most of the best products from them.

This bulletin, known as No. 210 of the Bureau of Mines, was printed by the State of Colorado as part of the coöperative agreement. It represents the assembled results of the investigations up to the present, together with material of a general nature necessary in a well-rounded presentation of the present state of knowledge of the subject. Copies can be obtained from the U. S. Bureau of Mines, Boulder, Col.

Railroad Rolling Stock and Accessories A1-23. Properties of Chilled-Iron Car Wheels. Part II, Wheel Fit, Static Load, and Flange Pressure Strains—Ultimate Strength of Flange. This report, Bulletin No. 134, of the Engineering Experiment Station, University of Illinois, Urbana, Ill., prepared by Messrs. J. M. Snodgrass and F. H. Fuldner, presents two additional phases of the investigation of the properties of chilled-iron car wheels conducted at the University of Illinois. This investigation had for its object the determination of the strains which may occur within a car wheel and the limitations of present designs, with the view of improving the chilled-iron car wheel and making it more satisfactory under present and future service requirements. The work was done under a coöperative agreement between the Association of manufacturers of Chilled Car Wheels and the University. Price per copy, 40 cents.

Refrigeration A1-23. Specific Volume of Saturated Ammonia Vapor. Several years ago the Bureau of Standards began the determination of the various thermodynamic properties of ammonia to establish an experimental basis for engineering tables to be used in the refrigerating industry. The present paper is the last of a series of papers on the determination of those properties under saturation conditions.

The specific volume, or the numerical reciprocal of density, of the saturated vapor was measured in the temperature interval —50 to +50 deg. cent. by two methods; one a direct method and the other an optical method. Ammonia of high purity was used in all of the measurements.

This Scientific Paper of the Bureau of Standards, No. 467, by C. S. Cragoe, E. C. McKelvy, and G. F. O'Connor, may be purchased from the Superintendent of Documents, Government Printing Office, Washington, D. C. Price, 5 cents.

B—Research in Progress

The purpose of this section of Engineering Research is to bring together those who are working on the same problem for coöperation or conference, to prevent unnecessary duplication of work, and to inform the profession of the investigators who are engaged upon research problems. The addresses of these investigators are given for the purpose of correspondence.

Fuels B1-23. Carbonizing Experiments on Lignite. As the result of a coöperative agreement between the Bureau of Mines and the Uni-

versity of North Dakota a series of experiments are being conducted at Grand Forks, N. D. on the carbonizing of lignite.

In conducting these experiments it was ever kept in mind that definite information was sought regarding a number of variables of unknown value and briefly, it was the aim to: (1) produce a well-carbonized lignite; (2) obtain a maximum throughout; (3) note the influence of the quality of lignite used on the performance of the oven and on the character of the carbonized product; (4) note the influence of the size of the lumps of lignite charged upon the character of product obtained and upon capacity; (5) eliminate the smoke nuisance; (6) study the performance of the cooler and the discharge apparatus ascertaining facts relative to its adaptability in preference to other types; (7) find out what the chief factors are that influence the production of a good quality of carbonized lignite, and make such changes in the oven structure as its operation indicated were necessary; (8) note the character, quality, yield and size of particles of the carbonized lignite produced; and (9) make certain laboratory studies during such delays in operation as are incidental to experimental work of this nature.

The program as outlined is being carried out, but on account of the fuel situation and other factors only a few different lignites have been tested. The same limitation applies to the study of the effect of sizes, but in spite of this fact the desired data relative to this factor are well in hand.

The results so far obtained are reported in the Bureau of Mines, Reports of Investigations, Serial No. 2441.

Heat Transmission B1-23. Heat Transmission Through Boiler Tubes. The effects of boiler scale, soot and oil upon the heat transmission through boiler tubes is the subject of an investigation being undertaken at the University of Illinois. Prof. A. C. Willard of the Department of Heating and Ventilation is conducting this research and Messrs. H. O. Croft and C. H. Cather are in direct charge of the experiments.

Instruments and Apparatus B2-23. Saybolt Universal Viscosimeter. A conference was held at the Bureau of Standards, November 14 with members of the American Petroleum Institute, as a result of which a committee of 5 members of the Institute was appointed to coöperate with the Bureau in expediting the more accurate standardization of the Saybolt universal viscosimeter.

The Institute and the Bureau are also coöperating with the Society of Automotive Engineers and the Interdepartmental Committee on Petroleum Products in the development of a numbering system for lubricating oils based on their viscosity.

Metallurgy and Metallography B1-23. Etching Reagents for Alloy Steels. The Bureau of Standards has been making a study of the problem of finding an etching reagent by which chromium carbide could be distinguished from vanadium carbide in a positive and satisfactory manner. Etching in a hot solution of potassium permanganate and sodium hydroxide for one minute darkens chromium carbide to a strong brown-red or brown color, while vanadium carbide remains uncolored and apparently unattacked. Another but less positive means of distinction is that obtained by electrolytic etching with a weak current in a dilute aqueous solution of ammonia or sodium hydroxide. The chromium carbide is eaten out, leaving a dark brown-red or brown cavity, while the vanadium carbide is eaten out apparently at a slower rate, leaving cavities which appear light.

F—Bibliographies

The purpose of this section of Engineering Research is to inform the profession of bibliographies which have been prepared. In general this work is done at the expense of the Society. Extensive bibliographies require the approval of the Research Committee. All bibliographies are loaned for a period of one month only. Additional copies are available, however, for periods of two weeks to members of the A.S.M.E. These bibliographies are on file at the headquarters of the Society.

Corrosion F1-23. Protective Metallic Coatings for the Rustproofing of Iron and Steel. A selected bibliography on corrosion of iron and steel and its prevention by metallic coatings forms an appendix to Bureau of Standards Circular No. 80. Apply Superintendent of Documents, Government Printing Office, Washington, D. C. Price 20 cents.

Petroleum and Allied Substances F1-23. Oil Shale—an Historical, Technical and Economic Study. A new bibliography dated July, 1922, forms an appendix to Bulletin No. 210 of the U. S. Bureau of Mines. It has been made as short as possible, consistent with the presentation of literature that covers oil shale from all angles. Address U. S. Bureau of Mines, Boulder, Colorado.

CORRESPONDENCE

Contributions to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities and policies of the Society in Research and Standardization.

Velocity of Steam in Pipes

To the Editor:

In an abstract on page 190 of Mechanical Engineering for March, 1923, there is raised the question of steam velocity in pipes.

In a paper on The Flow of Fluids Through Commercial Pipe Lines, by Wilson, McAdams, and Seltzer [*Jl. Ind. & Eng. Chem.*, vol. 14, p. 105 (1922)], the fact is brought out and supported by experimental results that the friction factor f in Fanning's equation is a function of DvS/z, where D = inside diameter of pipe in inches, v = average linear velocity in pipe line in feet per second, S = specific gravity of fluid, and z = viscosity in centipoises. Given a knowledge of these factors, any pipe-line problem for any fluid can be solved.

The difficulty in applying this equation to the flow of steam is our lack of knowledge of its viscosity. While the temperature coefficient of viscosity is known for several other gases, an extensive search of the literature has shown only a few determinations for steam at room temperature and 100 deg. cent. It would seem that this would be an interesting problem for the physics department in a university. The determinations should be made up to a temperature of 600 deg. cent., and at least three points taken between 400 deg. and 600 deg. The data up to 400 deg. cent. will probably follow a different law from those above 400 deg. Above the critical temperature (375 deg. cent.) Sutherland's equation for the temperature coefficient of viscosity may be expected to apply. The apparatus should be calibrated with air.

It would certainly be very desirable to add a better knowledge of the viscosity of steam to that of the other properties which are being so carefully worked out. Any one desiring to take this matter up will find a complete bibliography on the general subject in Bingham's recent book on Viscosity and Fluidity.

What is needed is not more empirical formulas, but the facts to put a fundamentally correct formula on a working basis.

After the experimental work on viscosity has been done by a physicist, then a careful correlation of the existing data should be undertaken by an engineer.

Geo. H. West.

San Francisco, Cal.

Mathematical Determination of the Modulus of Elasticity

To the Editor:

The writer feels gratified at the interest aroused by his proposed method of bending tests with thin strips, published in the December issue of Mechanical Engineering, as evidenced by the much appreciated comments of Prof. Wm. R. Bryans in the February issue, and of Messrs. E. A. Richardson and S. Timoshenko in the April issue.

While acknowledging the correctness of the writer's deductions, Professor Bryans asserts that the basic equation, $M = EI/\rho$ correctly applies only to infinite radii of curvature, and for finite values of ρ the results obtained can only be approximate.

To the writer's knowledge there is no such limitation in regard to ρ; the only assumptions underlying the above equation are: (1) The neutral plane of the loaded beam passes through the center of gravity of the given cross-section; and (2) the modulus of elasticity E is the same for expansion and compression. Here is the simple deduction of this basic equation: As seen in Fig. 1, the length

of the fiber element a-a before the beam is bent is $\rho d\alpha$; when the beam is bent its length becomes $(\rho + e)d\alpha$; therefore its relative expansion (or contraction, if situated below the neutral line) is:

$$\frac{(\rho + e)d\alpha - \rho d\alpha}{\rho d\alpha} = \frac{e}{\rho}$$

The fiber tension at the point α of the cross-section m-m will therefore be $E\frac{e}{\rho}\, dA$, where A denotes the cross-sectional area of the beam. Its moment M relative the axis O of the cross-section is $E\frac{e^2}{\rho}\, dA$, which, extended to all fibers of the cross-section, will be $\frac{E}{\rho}\,\Sigma e^2 dA = \frac{EI}{\rho}$, or $M = EI/\rho$. No limitation as to the magnitude of ρ enters into this deduction. Mr. Timoshenko makes the same statement, but the deduction is given here in full, for the sake of clearness.

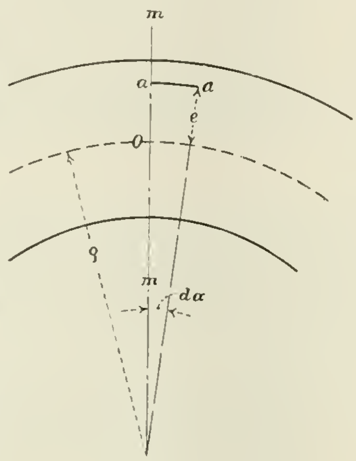


Fig. 1

Mr. Richardson in his comments very ably shows the possible effect of an error in the computation of I, the moment of inertia, concluding, as does also Professor Bryans, that the proposed method is far from mathematical precision.

Extending Mr. Richardson's method of calculation to the area $A = bh$ of the cross-section of the strip, the difference in the error percentages is—

$$\frac{dI}{I} - \frac{dA}{A} = \frac{db}{b} + 3\frac{dh}{h} - \left(\frac{db}{b} + \frac{dh}{h}\right) = 2\frac{dh}{h}$$

Here all depends on the thickness h and the measurement variation dh, both controllable factors. While the question as to how correctly a measurement may be taken may not properly be argued, it nevertheless must be conceded that even if the proposed method be not considered as an unconditional substitute for existing laboratory methods, it surely affords a sound practical expedient. Theoretically the chief point of interest of the method is its novelty: it makes possible for the first time the exact integration of the differential equation of the elastic curve, without the customary approximation of assuming $[1 + (\partial x/\partial y)^2]^{1.5} = 1$; also the determination of the cord tension of an archer's bow when the modulus of elasticity of the bow material is known.

The disadvantage of employing I instead of the cross-sectional area may be compensated by the large and easily measurable deformations in this method. This may account for the fact that in the two recorded tests with thin wooden strips, using a pocket rule and an ordinary spring balance, the results obtained were so near those given in engineering tables.

Mr. Timoshenko in his extensive and instructive comments considers the limitation imposed by the elastic limit and determines analytically and by certain experimental data the influence of the cross-sectional deformations on the bending of thin strips, showing how the above-mentioned basic equation may be made theoretically more correct by the introduction of a certain coefficient.

With regard to the elastic limit, attention is here called to the fact that in the bending-test device for thin strips illustrated in the December issue, provision is made for easily verifying in each test whether the bending is within or outside the elastic limit, without the need of any calculations, thus affording the possibility of its experimental determination; though some preliminary idea as to what the radius of curvature is likely to be near the elastic limit, as shown by Mr. Timoshenko, is naturally desirable.

As to the coefficients m and k introduced by Mr. Timoshenko to account for cross-sectional deformations, we are here on uncertain ground, but it may be of interest to note that this simple bending-test device for thin strips readily lends itself to the determination of these coefficients. As the differential elastic-curve equation has been integrated without any assumed approximation and the equations obtained are theoretically exact—in the absence of influencing cross-sectional deformations—and all factors are directly measurable, with the exception of E, the modulus of elasticity, which may either be taken from existing tables or determined directly by means of an extensometer, therefore all factors in these equations will be known except the said coefficients, which could accordingly be determined.

It would be gratifying if Mr. Timoshenko would publish a detailed description of his bending experiments with thin strips.

David Guelbaum.

Syracuse, N. Y.

Second Revision of A.S.M.E. Boiler Code, 1923

A HEARING is held by the Boiler Code Committee at least once in four years, at which all interested parties may be heard, in order that such revisions may be made as are found to be desirable, as the state of the art advances. The year 1922 became the period of the second revision and the Boiler Code Committee held a Public Hearing in connection with the recent Annual Meeting of the Society in December, 1922, to which the membership of the Society and every one interested in the steam-boiler industry was invited to attend and present their views.

For the convenience of every one interested, a printed schedule of the various proposed revisions had been published and distributed to all those who were invited to attend the Public Hearing and the opportunity was given thereat for the most careful consideration of all of the proposed revisions. As a result of the suggestions received at the Public Hearing, a number of modifications of the previously announced revisions were offered and in addition suggestions were received for still further revisions of the Code. All of these suggestions for modifications and new revisions have been carefully considered by the Boiler Code Committee and the result in modifications of revisions and additional revisions are here published.

It is the request of the Committee that these revisions be fully and freely discussed so that it may be possible for any one to suggest changes before the rules are brought to final form and presented to the Council for approval. Discussions should be mailed to C. W. Obert, Secretary to the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be considered by the Boiler Code Committee.

The revisions here published are limited to the paragraphs appearing in the 1918 Edition of the A.S.M.E. Boiler Code, and the paragraph numbers refer to the paragraphs of similar number in that edition. For the convenience of the reader in studying the revisions, all added matter appears in small capitals and all deleted matter in smaller type in brackets.

Modifications of Revisions

Par. 9 REARRANGE PARAGRAPH AS PRINTED IN JULY 1922 AND APRIL 1923 ISSUES OF MECHANICAL ENGINEERING AS FOLLOWS:

9 The use of bessemer steel is prohibited for the pressure parts of boilers. When the maximum allowable working pressure exceeds 160 lb. per sq. in., cross-pipes connecting the steam and water drums of water-tube boilers, headers, cross-boxes and all pressure parts of the boiler proper over 2-in. pipe size, or equivalent cross-sectional area, shall be of wrought steel, or cast steel of Class B grade, as designated in the Specifications for Steel Castings. Malleable iron may also be used when the maximum allowable working pressure does not exceed 200 lb. per sq. in., provided the form and size of the internal cross-section perpendicular to the longest di-

Note: Matter in caps—added matter; Matter in smaller type in brackets—to be deleted.

mension of the box is such that it will fall within a 7-in. by 7-in. rectangle.

Seamless tubes or lap-welded pipe may be used for drums or other pressure parts of a boiler provided such tubes or pipes conform to the specifications for welded and seamless steel and wrought-iron pipe, and provided also that the outside diameter of the tubes or pipes does not exceed 20 in.

Par. 21 Replace revised form printed in April 1923 issue of Mechanical Engineering with the following:

21 *Tubes* and nipples *for Water-Tube Boilers. a* Tubes and nipples for use in water-tube boilers for all pressures in excess of 160 lb. allowable working pressure shall be seamless steel. Up to and including 160 lb. pressure lap-welded steel or iron may be used.

b The maximum allowable working pressures for steel or wrought-iron tubes or nipples used in water-tube boilers shall be for the various diameters and minimum gages measured by Birmingham wire gage, as given in Table 2. Redrawn pipe not to exceed $1\frac{1}{2}$ in. standard pipe size which meets the pipe specification may be used for water-tube boilers for a working pressure not to exceed 200 lb. per sq. in., when screwed in the sheet, provided the wall thickness is at least 50 per cent greater than the minimum wall thickness required by Table 2. The maximum allowable working pressure for copper tubes or nipples used in water-tube boilers, shall be for the various diameters and minimum gages measured by Birmingham wire gage as given in Table $2\frac{1}{2}$, but not to be used for pressures to exceed 250 lb. Copper tubes shall not be used with superheated steam.

Table 2 Change heading to read as follows:

Table 2 Maximum Allowable Working Pressures for Steel or wrought-iron Tubes or nipples for Water-Tube Boilers.

Table $2\frac{1}{2}$ Change heading as given in April 1923 issue of Mechanical Engineering as follows:

Table $2\frac{1}{2}$ Maximum Allowable Working Pressures for Copper or wrought-iron Tubes or nipples for Water-Tube Boilers.

Par. 185 Replace revised form printed in December 1922 and April 1923 issues of Mechanical Engineering with the following:

185 When shell plates exceed 5/8 [9/16] in. in thickness in horizontal-return-tubular boilers, the portion of the plates forming the laps of the circumferential joints, where exposed to the fire or products of combustion, shall be planed or milled down as shown in Fig. 8, to a thickness of not over 9/16 [1/2] in. provided the requirement in Par. 184 is complied with. Where plates are planed or milled down it shall be for the entire circumference of the joint, and the fillet at the edge of the planing may [shall] be not less than 1 in. radius.

Par. 230 Insert the following before the added matter given in the December 1922 issue of Mechanical Engineering:

Sling stays, if used between crown bars and boiler shell or wrapper sheet, shall be proportioned so as to carry the entire load without considering the strength of the crown bars.

Par. 253 Replace first section of revised form in December 1922 issue of Mechanical Engineering with the following:

All holes in braces, lugs and sheets for rivets or staybolts shall be drilled full size with plates, butt straps and heads bolted up in position, or they may be drilled or punched not to exceed 1/4 in. less than full size for plates over 5/16 in. in thickness and 1/8 in. less than full size for plates not exceeding 5/16 in. in thickness and then drilled or reamed to full size with plates, butt straps and heads bolted up in position.

Par. 257 Add the following to the revised form given in December 1922 issue of Mechanical Engineering:

or splitting the calked sheet.

Par. 259 Replaced revised form given in July 1922 issue of Mechanical Engineering with the following:

259 A manhole reinforcing ring, when used, shall be of wrought or cast steel [or wrought iron], and shall be at least as thick as the shell-plate thickness required by Par. 180.

Par. 278 Insert the words "with bevel seats," after the words "intermediate lift" at the end of the seventh line of the matter given in the April 1923 issue of Mechanical Engineering.

Par. 325 Revise second sentence of revised form in July 1922 issue of Mechanical Engineering as follows:

The shearing and crushing stresses on the rivets or studs used for attaching the lugs or brackets shall not exceed 8 per cent of the strength given in Pars. 15 and 16.

Par. 332 Omit next to last section of revised form given in April 1923 issue of Mechanical Engineering beginning with "Portable Boilers of 100 hp."

Par. 333*c* Replace revised form given in April 1923 issue of Mechanical Engineering with the following:

c On traction, portable or stationary boilers of the locomotive type or Star water-tube boilers—on the furnace end, above the handhole. Or on traction boilers of the locomotive type—on the left wrapper sheet forward of the driving wheel. In addition to the stampings herein provided, portable boilers of 100 hp. or less shall, when possible, have the stamping herein provided applied on a non-ferrous plate 3 in. × 4 in. in size which shall be as nearly as practicable, irremovably fastened to the boiler near the water-column connections.

New Revisions

Par. 17 Revised:

Thickness of Plates. The minimum thickness of any boiler plate under pressure shall be 1/4 in. The minimum thickness of plates in stayed surface construction shall be 5/16 in.

Par. 184 Add the following section:

d The distance from the centers of rivet holes of circumferential joints to the edges of the plate shall not be less than the diameter of the rivet holes.

Par. 190 Revised:

190 A horizontal-return-tubular boiler shall not have a continuous longitudinal joint over 12 ft. in length. With butt and double strap construction longitudinal joints of any length may be used, provided the tension-test specimens are so cut from the shell plate that their lengthwise direction is parallel with the circumferential seams of the boiler, and the tests meet the standards prescribed in the specifications for boiler-plate steel.

Par. 219 Revised:

219 When stay rods are screwed through the sheets and riveted over, they shall be supported at intervals not exceeding 6 ft. In boilers without manholes, stay rods over 6 ft. in length may be used without support if screwed through the sheets and fitted with nuts and washers on the outside provided the least cross-sectional area of the stay rod is not less than that of a circle 1 in. in diameter.

Par. 263 Revised:

263 The minimum width of bearing surface, for a gasket on a manhole opening shall be 11/16 [1/2] in. No gasket for use on a manhole or handhole of any boiler shall have a thickness greater than 1/4 in. when compressed.

Revisions on Miniature Boiler Code

M-19 Revise first section to read:

M-19 All boilers referred to in this section shall be plainly marked with the manufacturer's name, maximum allowable working pressure, which shall be indicated in arabic numerals, followed by the letters "lb.," and serial number. All boilers built according to these rules shall be marked A.S.M.E. Std.—Miniature. Individual shop inspection is [not] required for miniature boilers in the same manner as for power boilers.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities Papers and Proceedings of

The American Society of Mechanical Engineers

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Technical Literature

In a recent issue of the *Carnegie Technical Journal*, Prof. W. Trinks directs attention to the dearth of good technical books which give information about the various specialties of engineering. He traces the reason for this to the fact that the compensation received by authors is not sufficient to attract competent men. What books are written, are written for altruistic reasons or to achieve a reputation. Textbooks dealing with fundamentals are of course in a different class. Furthermore, the progress of engineering art and science is so rapid that technical books become obsolete at an alarming rate. He draws attention to the paucity and inadequacy of engineering libraries in the country, and points out the large number of good technical books in foreign tongues.

Professor Trinks' statements serve to emphasize the value of the technical press and the proceedings of the technical societies, both of which present valuable information concerning current developments. The intelligent clipping and indexing of this material should therefore be the duty of the alert practicing engineer. The monthly and annual printed indexes of engineering literature, such as the Engineering Index in Mechanical Engineering, should be of inestimable value in this respect. In view, therefore, of this value of current engineering literature, does it really seem necessary that time should be spent on specialized technical books which become obsolete quickly and yield but a relatively small compensation to the author?

Exception would probably be taken by many American engineers to Professor Trinks' high opinion of foreign books. The fact remains, however, that foreign printing costs and the attitude of foreign engineers are conducive to a greater volume of good technical books of the specialized type.

As to American engineering libraries, satisfactory facilities are provided in most of the large cities. New York, Boston, Pittsburgh, Cleveland, Chicago, and Washington all possess adequate collections of technical books which are available for reference. Recently Denver has taken steps to establish an engineering library.

The photostat service of the Engineering Societies Library aims to provide desired information where it is not possible to send out the book or periodical in which it appears. At the present time it is the practice of the Library to loan duplicate copies of its books to members of the National Engineering Societies, and obviously a helpful step in this respect would be the broadening of this loan service.

A.E.S.C. Completes Sixth Year of Successful Service

The increasing scope and influence of the American Engineering Standards Committee as a clearing house for engineering and industrial standardization is shown by the 1923 Year Book of this organization. Its success should be extremely gratifying to those who originated the committee in 1917 with a view to coördinating the standardization work of the national engineering societies. From its humble start with four coöperating bodies it now reports 23 member bodies, 205 participating agencies with duly accredited representatives and 917 individuals engaged in committee activities. And the end is not in sight, for the possibilities of industrial development through standardization and simplification are unfolding in a manner that has led the A E S C (without punctuation), as it desires to be designated, to develop a new financial policy whereby industrial organizations may become sustaining members and contribute directly to the work.

The success of this Committee's activity is due to the fundamental principle of procedure by which the A E S C as an organization does not initiate projects but rather administers and forms policies for the carrying out of the work. The actual work of securing agreement on standards falls to the sectional committees, organized by the national societies and associations which accept sponsorship for them. The A E S C participates by determining whether the work should be undertaken, by designating the sponsors, and by ultimately approving the result as an "American Standard" or a "Tentative American Standard."

The sectional committees are organized to assure representation of all interests, and the project is initiated with a conference which brings all of the conflicting ideas together and affords an opportunity for ironing out differences.

The A E S C has a very broad function in its coöperation with foreign national standardization bodies. Progress has been made in ball-bearing standardization, different proposals having been presented to various foreign bodies as the basis for international agreement.

This coördinated standardization movement has passed through many vicissitudes. However, its present firm establishment gives ample assurance that the important function which it is to perform will be carried out in a manner entirely worthy of the engineering profession.

State Rights and Water Power

The recent correspondence between the Governor of New York and the Governor of Pennsylvania on state water-power rights bids fair to become classic. Governor Smith of New York holds out for state rights in the water power from navigable streams and proposes to develop the water powers of his state for the exclusive use of New York. Governor Pinchot agrees with the engineering conclusion that interconnected systems are necessary for cheap, reliable hydroelectric power. His words, which we quote below, are worthy of careful consideration.

> After eighteen years of study and work on this problem, I have come confidently to expect the growth of a nation-wide interlocking power system........The freedom of commerce among the several states, the unrestricted exchange across state lines of service, goods and resources, guaranteed by the Federal Constitution, is the strongest man-made basis of the prosperity of each state. This consideration applies not only to energy riding in a coal car but equally to energy flowing over a wire, whether the burning of fuel or the falling of water was the source. Furthermore, really cheap power cannot be supplied to consumers unless the burning of coal and the flowing of water contribute their energy to a common reservoir for the common supply of industries, farms, homes and railroads. Such a system must transcend state lines and is likely to become nation-wide.

In the meantime, Massachusetts is planning to analyze the power needs of its growing industries, and the Associated Industries of Massachusetts have selected Charles T. Main, Past-President of The American Society of Mechanical Engineers, as chairman of a committee to determine the kinds and amounts of present powers, the cost of each, and the increase in that cost in the last ten years; the available new sources of power both within and without the borders of the state, the probable demand for such power, and the cost of supplying it to the industries and public utilities of the commonwealth of Massachusetts.

Business Cycles and Unemployment

Report of Committee Appointed by Secretary Hoover Suggests Methods for Preventing Widespread Unemployment During Periods of Depression

THE report of the committee appointed in September, 1921, by Secretary of Commerce, Herbert Hoover, to investigate the problem of unemployment as related to the fluctuations of the business cycle, has been made public. The committee, after stating the questions to be considered, discuss the nature and effects of the business cycle at some length, using the term to describe the series of changes in business conditions which are characterized by an upward movement toward a boom, followed by a downward movement into depression. As a result of their analysis of the problem the committee arrive at a number of conclusions which they embody in a series of recommendations relating both to the direct prevention of expansion and inflation and to the prevention of unemployment. The outstanding features of these recommendations are presented in the following extracts from the report.

Collection of Fundamental Data. In many industries the coöperation necessary to form a common pool of fundamental facts is made possible through trade associations, to which current figures are reported by their members. In other industries such figures, in whole or in part, are supplied directly to Government bureaus. In an endeavor to put in more available form the sum of information now current and to add to it Secretary Hoover has established in the Department of Commerce a monthly survey of current business which summarizes the data available from all sources that bear upon this major problem of business trends.

What is evidently needed is an increase in the resources of the Department of Commerce and a larger degree of coöperation with the department in coördinating and extending business information, so that business men and bankers may know promptly the facts about the rate of production measured in physical units, the stocks on hand and in transit, the trend of prices, the volume of sales, and the trend in money rates. There is great need also for recording data as to the speed of freight movements so as to show whether the output of farms and factories is being promptly distributed to the consumer or is being delayed in transit because of freight congestion.

Larger Statistical Service. The committee recommend the expansion and standardization of the statistics now collected by state and federal bureaus, the publication of employment statistics by the Federal Bureau of Labor Statistics, and the final summation and publication of all of these statistics by the Department of Commerce, in order that there may be promptly available a connected, uniform series of facts about the trend of business.

In collecting figures on stocks and production the following list of commodities has been suggested to the committee by experts as most significant in showing the trend of the business cycle:

1 Raw wool and woolen textiles
2 Raw cotton and cotton textiles
3 Hides and leather and shoes
4 Iron and steel and leading fabricated products, such as structural steel and standard tools
5 Zinc, lead, and copper and leading products of each
6 Bituminous coal.

Research. A primary necessity is the collection and dissemination of fundamental data. Following this, we need further development of special research into economic forces, into business currents, and into broad questions of economic method. Industries generally recognize the need of research in physical science. Laboratories have been equipped with large staffs of trained workers. A similar recognition of the importance of economic research and the interpretation of economic facts would be the beginning of better control of business conditions by business men.

The forecasting of probable business trends is difficult and can never be undertaken successfully by any kind of public institution, except in a limited field. Business men must themselves form their own fundamental judgments when adequate data are furnished. Research as to the effect of different trends and economic forces is, however, a different problem from forecasting. Such research should be carried on continuously by the Government bureaus, because the data available to these bureaus are more extensive than those available to other institutions, which must depend upon published summaries of Government data.

Control of Credit Expansion by Banks. The individual banker, like the individual business man, may properly be asked to assume some measure of responsibility. If only in his own interest, his policies should be determined by the general business situation as well as by the apparent soundness of the particular transactions his customers ask him to finance. One suggestion is that when prices are rising and business is expanding, bankers should ask borrowers to maintain an increasing ratio of quick assets to current liabilities.

Control of Inflation by the Federal Reserve System. The Federal reserve banks now hold, as a result of the World War, a much larger amount of gold than would suffice to support all of the credit which American industry and agriculture can possibly need on anything like present price levels. With the return of more prosperous conditions in Europe a considerable part of this gold will naturally leave us. Meanwhile this excess gold might become the basis of a disastrous inflation of our domestic credit, which would be followed by an even more disastrous collapse when the gold goes out. This is the problem which faces us in the development of the Federal reserve system to its maximum usefulness, and it is a problem worthy of most careful and thorough study by bankers and associations of bankers.

Control by Business Men of the Expansion of Their Own Industries. The committee have seen numerous instances in which the individual business man, by conducting his business with reference to the business cycle, has avoided dangerous overextension of inventories and fixed capital which in many other instances resulted in unemployment and business failure during the cycle just past.

Planning production in advance and with reference to the business cycle, laying out extensions of plant and equipment ahead of immediate requirements with the object of carrying them out in periods of depression and carrying through such construction plans during periods of low prices in conformity with the long-time trend, the accumulation of financial reserves in prosperity in order to mark down inventories at the peak, and the maintenance of a long view of business problems rather than a short view, will enable firms to make headway toward stabilization.

Control of Private and Public Construction at the Peak. One method by which periods of expansion might in part be controlled is through the cessation and postponement of construction by the Government, railroads, public utilities, and private owners in boom periods when prices are high. Reserves built up in periods of high earnings and expansion are then spent for construction during periods of depression. When this policy is more generally followed it will be of peculiar value, as it will tend to keep low the ratio of fixed investment to productive capacity, to the great advantage of industry.

Holding back public works and private construction for periods of depression not only gives employment to large numbers of workers when it is most needed, but creates a demand for raw materials for construction which in turn stimulates other industries to offer employment. It maintains the buying power of those directly or indirectly employed, it creates a market for goods, and enables the workers, directly or indirectly employed to buy the products of other industries. Finally, construction work in a period of industrial depression, when costs are lower, is economical.

The essential steps in any general program are to plan construction work, private or public, long in advance with reference to the cyclical movement of business, and in the case of public works to pass the necessary legislative appropriations when facts about the trend of business show that it is sound policy to spend money for such purposes.

Public Utilities. In the interest both of utilities and of the buying public it is obvious that the normal time to finance new construction or improvements in public utilities is in periods of depression, when interest charges are reasonable and costs of construction low. In so far as the managers of utilities and public-service commissioners can regulate construction in order to fill up the valleys and lower the peaks of the business cycle they will aid in alleviating the extremes of the cycle, and by means of their economies they will keep their capital investment from unnecessary expansion, to the advantage both of the utilities and of the public.

Unemployment Reserve Funds. Nothing is more demoralizing for wage earners than the feeling of insecurity of employment. Unemployment and the fear of unemployment are powerful causes of discontent. The idea of employer, employee, or both, contributing during periods of employment to a reserve fund under separate or joint control to help sustain the worker when unemployed in periods of depression and to equalize and stabilize his purchasing capacity merits consideration.

Employment Bureaus. We do not regard an employment service a having a direct and immediate effect upon the business cycle. We do believe that if such employment bureaus are organized throughout the country, their reports will show the demand for labor and the number of workers seeking positions and will therefore be another measure of business conditions. If employment bureaus are organized effectively enough to insure transfer from one position to another with the least possible loss of time, they will make labor more immediately available and thus prevent loss of production for the employer and loss of income for the wage earners, thus helping to maintain the level of purchasing power.

The personnel of the committee signing the report is as follows: Owen D. Young, chairman of the board, General Electric Co., chairman; Joseph H. Defrees, former president United States Chamber of Commerce; Mary Van Kleeck, Russell Sage Foundation; Matthew Woll, vice president, American Federation of Labor; Clarence M. Woolley, president American Radiator Co.; Edward Eyre Hunt, secretary of the President's Conference on Unemployment, secretary.

In its work, the committee received the assistance of appropriations toward its cost from the Carnegie Foundation and services contributed by the National Bureau of Economic Research, the Russell Sage Foundation, the Federated American Engineering Societies, the United States Chamber of Commerce, the American Federation of Labor, the American Statistical Association, the American Economic Association, the Bureau of Railway Economics, the Department of Commerce, and a number of other bodies.

Hydroelectric Power for the Metropolitan District

Availability, Cost, Service Requirements, Operating Difficulties, and Transmission Problems Discussed at Meeting of the New York Sections of National Engineering Societies

THE New York sections of the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, and the American Institute of Electrical Engineers held a joint meeting in the Engineering Societies Building, New York, on March 21, at which five speakers discussed the economical use of hydroelectric power for the New York-New Jersey Metropolitan district. The presiding officer was Calvert Townley, chairman of the New York Section A.I.E.E., who emphasized the vital need of an adequate future supply of power for this district and the importance of focusing on this need the attention of all engineering societies.

Coördinated Statement of the Problem

F. W. Scheidenhelm,[1] cited the principal obstacles to the use of hydroelectric power in the Metropolitan district as:

1. Limited information, or, more accurately, limited appreciation of the extent to which hydroelectric power could be made available and of the method of utilizing such power, especially in combination with steam-electric power
2. Uncertainty or disagreement as to the relative cost of delivered hydroelectric power compared with the cost of steam-electric power performing the same service
3. Doubt as to the quality of service on part of hydro plants and of connecting transmission lines
4. Legal difficulties, involving especially the means for acquiring necessary lands and rights, and
5. Lack of definite and continuing policy on part of the states concerned.

Colonel Scheidenhelm pointed out that the problem was essentially one of using hydroelectric power in combination with large sources of steam-electric power supply. He called attention to the fact that greater hydro capacity was installed under combined hydro and steam operation than if the same water power were to be developed to serve an independent market. He also pointed out that the utilization of hydro power would introduce financial economies because fixed charges on investment for steam development averaged from twenty to forty per cent more than for hydro. A greater use of water power would ease congestion on railroads.

For the combined systems, such as would obtain in the Metropolitan district, there would be the increased assurance of continuous service which resulted from diversity of sources of power supply. Thus the possible ill effects of labor difficulties at the coal mines, on the railroads, or in the steam-electric power plants themselves would be considerably mitigated as compared with systems relying entirely on steam-electric power.

Greater New York and Westchester County were separable from northeastern New Jersey only on political, not economic, grounds. The Hudson River was not a barrier in itself. It happened that on each side of the river the power market was such that it could independently utilize large quantities of hydro power, whether high-load-factor power from the Niagara and the St. Lawrence or low-load-factor power from an interior stream. Nevertheless, it was clear that in order to obtain the fullest benefits from the use of hydro power, state boundaries should not be allowed to become barriers to proper economic development.

Availability and Cost of Delivery

W. S. Murray[2] presented facts as to the availability of water power and cost of delivery. He referred to the Superpower Survey published in 1921 as a "formula of procedure" for unified development.

He considered three rivers as hydroelectric possibilities at or within two hundred miles from the metropolitan load centers—the Hudson, the Delaware, the Susquehanna. The maximum number of kilowatt-hours must be provided from these developments to reduce unit cost, and in this connection the impounding of waters of reservoirs was very important. The total capacity already developed in the Susquehanna was 83,500 kw. which should be increased in 1930 by approximately 100,000 kw. In an average year such a development would produce 1,230,000,000 kw-hr. In more distant years, using the total available head of 204 ft., a total capacity of 620,000 kw. would be justified. The Delaware River was fundamentally a storage river. As of 1930 it would appear to be economical to develop 350,000 kw., producing during an average year 1,250,000,000 kw-hr. at a cost at the river of slightly more than 6 mills. The Hudson also offered valuable storage opportunities which could be economically developed to 150,000 kw. as of 1930 with an average yearly capacity of 900,000,000 kw-hr. at a cost at the river of slightly under 6 mills.

Mr. Murray also stated that the low development costs on the Niagara and St. Lawrence made it possible to place electric energy within the Metropolitan load center at less cost than from the Hudson. In concluding, he stated the results of a recent intensive investigation that a combination of steam and hydroelectric energy could be developed within a radius of one hundred miles and delivered into the existing distribution systems at a cost not exceeding 7 mills, provided the load factor of the delivered power did not fall below 65 per cent. A bulk of 500,000 kw. could be made available in two years and increased to twice that amount if desired.

Service Requirements

George A. Orrok[3] outlined the service requirements which hydroelectric power must meet. He emphasized the importance of reliable service and outlined the severe operating conditions in the Metropolitan district. He estimated that in 1930 the output in the Metropolitan district would probably run between ten and twelve billion kilowatt-hours with a peak lying between two and one-half and three million kilowatts. In closing, Mr. Orrok discussed the price at which hydro powers were attractive as follows: Mr. Murray had mentioned 7 mills as the probable selling price of hydroelectric power delivered at the outskirts of the district. If there was added to this the connection cost of 2.5 mills, we could roughly approximate the condition under which this current might be utilizable by the power companies. With coal at \$8 a ton and a 60 per cent load factor, a price of 6 to 7 mills delivered at the district boundary seemed to be, roughly, about the point where the hydroelectric ceased to be attractive. With coal at a lower price or water which must of necessity be given a higher load factor, the limit of attractive price would be lower. Even at the figures given, the water seasonal variation must work in well with the district variation or there would be no economic advantage. The figures which he gave had been based on using as much water on the peak as possible, but even with this condition the night watch must waste water unless large diurnal storage was provided.

Factors Affecting Quality of Service

F. A. Allner,[4] from his experience in the operation of the Holtwood Plant on the Susquehanna River, told of the factors that affected quality of service. Ice trouble seemed to him the most important hydraulic trouble to guard against. This might be of three kinds, local, up-river, and frazil ice, the latter being the most dangerous. This could be eliminated by maintaining the highest possible temperature in the power house, by continuous movement of guide-vane mechanisms, and by steam or electric heating of submerged metal parts where the ice was inclined to stick. Mr. Allner compared the service troubles in the highly complicated steam plant with its complicated auxiliary apparatus with the hydro plant with its few sturdy and easily repaired parts. He also emphasized the ability of the hydroelectric plant to take on its load quickly. At the Holtwood plant a water-wheel unit was brought from standstill to full load in 21 sec.

[1] Consulting engineer, New York, N. Y.

[2] Consulting engineer, New York.

[3] Consulting engineer, New York. Mem. A.S.M.E.

[4] General superintendent, Pennsylvania Water and Power Co., Baltimore. Mem. A.S.M.E.

Lorin E. Imlay[5] discussed the reliability of long-distance transmission and pointed out that long-distance service was growing better from year to year, relating his experience in transmitting current from Niagara Falls over about 200 miles of overhead circuits.

In the discussion which followed, John P. Hogan[6] advanced the thought that not only should state boundaries be disregarded in water-power development, but perhaps national boundaries ought not to be considered. He stated that the only distant powers that might be economically used in the Metropolitan district were those that were practically continuous and could be delivered in the city at a relatively high load factor. He also emphasized the importance of considering each stream by itself and of a policy of uniform progressive development of that stream.

W. S. Finlay[7] summarized the problem of the Metropolitan district as the necessity of determining the character of the service it considered necessary to its welfare and comfort, recognizing the cost to be paid, and then bending every energy to the conservation of its resources and the development of such resources as affected its power service and supply.

Progress in Fatigue of Metals Investigation

DURING the year 1922, definite and important progress was made in the experimental work of the Fatigue of Metals Investigation at the Engineering Experiment Station of the University of Illinois. Engineering Foundation has continued its coöperation and the committee of the National Research Council has advised on program and report. A second report giving results and conclusions in detail is on the press as Bulletin No. 136, of the Experiment Station. This report, in slightly condensed form, will be printed also in the annual publication of Engineering Foundation, to be ready for distribution in May.

Interest in this investigation has spread and its practical value has come to be more widely appreciated. During 1922 outside funds for support of the project came wholly from the General Electric Company. Its officers have expressed high satisfaction with the work done.

Extension for two years is assured by the provision of additional funds to the amount of $30,000. The University of Illinois, the National Research Council and Engineering Foundation will continue to coöperate. The following industries will participate financially and in other ways: General Electric Company by a substantial addition to its preceding investment of $30,000; the Allis-Chalmers Manufacturing Company, the Copper and Brass Research Association, representing the most important producers and manufacturers of copper and its alloys, and the Western Electric Company. Several other companies are expected to join, in addition to a number mentioned in the first report (Bulletin No. 124, of the Engineering Experiment Station), which contributed materials and services of considerable value.

On the new part of the program are tests of steels at high temperatures, such as obtain in modern steam-engineering equipment and in internal-combustion engines, and a study of non-ferrous metals, particularly the copper alloys.

The investigation continues under the immediate charge of Prof. H. F. Moore and has the general supervision of Prof. Arthur N. Talbot, as the head of the Department of Theoretical and Applied Mechanics, in the Engineering College of the University of Illinois.

Small-Motored Planes

THE newspaper reports of the gliding competition in France on April 1 state that the winner made four flights in a glider fitted with a seven-horsepower auxiliary motor. One of the flights lasted a quarter of an hour and a speed of ninety kilometers per hour was attained—a unique performance. The accounts are not sufficiently explicit to enable a judgment to be formed as to the real value of the flights, but enough has been made known to emphasize the possibilities of planes driven by small motors as an economical and popular means of locomotion.

[5] Consulting engineer, Niagara Falls Power Co.

[6] Consulting engineer, William Barclay Parsons, New York.

[7] Vice-president, American Water Works & Electric Co. New York, Vice-president A.S.M.E.

A.S.M.E. Meeting at Montreal to be Popular

MONTREAL, where the Spring Meeting of The American Society of Mechanical Engineers will be held, has the requisites needed to insure the success of the gathering: excellent hosts, a good technical program, and interesting excursions. The meeting will start on Monday, May 28, will continue for four days, and will be participated in by the members of the Engineering Institute of Canada. The technical sessions will be held at the Engineering Institute Building and at the Mt. Royal Hotel, the headquarters hotel of the meeting.

Two sessions will be devoted to Hydroelectric Power. There will also be sessions dealing with Management, Railroads, Port Development, Textiles, Fuels, and Machine Shop Practice. The afternoons will be set apart for visits to points of historic and scenic interest about Montreal, and on Tuesday and Wednesday evenings there will be novel entertainments. The Montreal Branch of the Engineering Institute of Canada is providing the entertainment for a smoking concert on Tuesday evening, and on Wednesday evening there will be a dinner dance at the Mt. Royal Hotel.

Plans are under way for an excursion by boat from Toronto to Kingston for those who come from points west and southwest of Buffalo, and an automobile trip is being arranged for those who care to drive from New York and the New England district. Following the meeting there will be excursions to Grand Mere, Shawinigan Falls, and Quebec. All indications point to a well-attended, enthusiastic meeting.

The details of the meeting to date have appeared in the *A.S.M.E. News* and complete particulars of the final program will be given in the issue of April 22.

"The Four C's Guide Post"

AT A RECENT meeting of the New York Railroad Club, E. K. Hall, vice-president of the American Telephone and Telegraph Company, spoke on the need for team play in our industrial organizations. Every man in the company must want to make the enterprise a success and be willing to do his share, whatever that may be, to attain that object. Mr. Hall did not believe that a successful formula had been found, but he did tell about what he called "The Four C's Guide Post" which may be explained in his own words, as follows:

"*Contact:* We start on the theory that one of the first things we have got to do is to get some contact between the management and the men. The men have been separated—separated geographically, and separated by an organization chart that starts with the president and, by the time it gets down to the man in the ranks, is way down in the depths. He could not go up that steep ladder if he was a steeple climber. We have got to find some means to get the people together—the management and the men.

"*Conference:* Getting them together is not enough. You get them acquainted, acquainted so they know each other. How do you get acquainted with a man? You do not get acquainted with him until you talk to him a little bit. He tells you what he thinks and you express an opinion and you size each other up, and that is the way you get acquainted. You are not acquainted when a man says, "Mr. A, meet Mr. B." That is contact, but not acquaintance. We say you have got to have something more than contact, you have got to have conference, you have got to talk things over. That is the second C.

"*Confidence:* Assuming you have a reasonably good bunch of people in the industry you are engaged in, if you talk together long enough and discuss things long enough and interpret yourselves to each other, that will inspire confidence. Then you are getting somewhere.

"*Coöperation:* The minute the men have confidence in the management and the management begins to have confidence in the men—and you cannot have one without the other, because the men are not going to have a whole lot of confidence in a manager who does not know them—it is very easy to coöperate, and that is the fourth C. That is team play. That is what we have got to have in the industry."

The Federated American Engineering Societies

Coal-Storage Survey

PROBABLY no decision reached by the Executive Board of American Engineering Council at its meeting in Cincinnati, Ohio, March 23 and 24, 1923, deserves higher commendation than that relating to a coal-storage survey. An authoritative statement covering the engineering, chemical, and economic factors involved in the storage of coal, and the influence of those factors on storage at the mine and by various classes of consumers, should be of prime importance in solving the complex coal situation. Many have contended that the widespread practice of storing coal by consumers would materially reduce the intermittent aspect of the coal industry; would result in an ample supply of coal at all times; would even up the demand for transportation facilities; would enable a larger resort to water transportation; would reduce operating and transportation expenses, and therefore would lead to a reduction in the cost of coal to the consumer. The compilation and analysis of complete data on all of the important factors involved should form a report as valuable as that on the Elimination of Waste in Industry.

In forming the committee to undertake the work the F.A.E.S. proposes that each of the following groups shall be represented: Bituminous and anthracite coal mining, transportation, public utilities, Bureau of Mines, equipment, chemical engineering, and any others that may be able to contribute scientific and fundamental information. W. L. Abbott, chief operating engineer, Commonwealth Edison Co., Chicago, has been chosen as chairman of the committee, which will develop its own plans, direct the investigation, employing the necessary assistance, and prepare the report.

The plan has the full endorsement of Secretary Hoover, Dr. George Otis Smith, vice-chairman of the U. S. Coal Commission, Mr. Wadleigh, U. S. fuel administrator, and Dr. H. Foster Bain, director of the Bureau of Mines. The work of the Department of Commerce and the Coal Commission, which are studying other features of the coal industry, and that of the F.A.E.S. committee will be so coördinated as to avoid duplication, confusion, and conflict. It is hoped that the report may be completed not later than November 1, 1923.

Storrs Plan of Domestic Coal Storage

EARLY in March, in a conversation with the Executive Secretary of the F.A.E.S., John Hays Hammond, chairman of the U. S. Coal Commission, voiced the desire of the commission for the coöperation and assistance of the engineers of the nation in its work and suggested a line of specific activity. Mr. Hammond emphasized the importance of coal storage and stated that it is a more difficult task to secure the storage of domestic coal than that of coal purchased by large users. He proposed a movement for a larger storage of domestic coal and urged that the engineers of the country lend their support to such a movement.

If engineers will point out to their clients and employers the advantages, accruing both to the public and to the coal industry, which can be secured if coal is stored during the summer, it is believed that they will be willing to arrange for the domestic coal purchases of their employees.

The plan which he advocated, one which has particularly impressed the Coal Commission, was devised by L. S. Storrs, of the Connecticut Company, New Haven, Conn. Under that plan the employee submits to his employer, prior to April 1, an estimate of his winter fuel needs. Delivery is to be made at the option of the retail dealer during the six months following. Full payment for the coal will be made by the company at the time of delivery. The company is reimbursed by deducting the cost of the coal from the employee's salary in monthly instalments over the six months' period.

Under this plan the employer purchases the coal at the best possible price and secures delivery early in the season. The employees, many of whom are accustomed to buying coal in very small lots during the period of highest prices and distribution difficulties, can make substantial savings and be assured of a sufficient quantity of coal.

Mr. Hammond's suggestion was transmitted immediately to the liaison officers of the member societies and, while at the time of writing reports of action taken are not available, a large number of inquiries from individual engineers and from companies as to details of the Storrs plan have been received at F.A.E.S. headquarters. Several large companies propose to adopt the Storrs plan or some similar method. Officials of the Department of Commerce, the Coal Commission, and the Bureau of Mines interested in the problem of coal storage have all expressed approval of the plan, and in many quarters it has been enthusiastically received. It is hoped that engineers will lend their fullest support to the movement.

Cincinnati Meeting of the Executive Board

IN ADDITION to the coal-storage decision, the Executive Board took action on a number of important matters at its Cincinnati meeting, and a number of interesting progress reports were presented. The Committee on Transportation, authorized at a meeting of the Committee on Procedure in February, had made a preliminary survey of the problem of transportation and advocated coöperation with a number of national organizations which have been working on it for some time. The Executive Board approved that policy. Max Toltz, of St. Paul, is chairman of the committee.

The Board voted to assist in the movement to bring about uniform safety legislation. In a statement on this subject issued recently by the F.A.E.S., both state and national legislation are recommended. Congress is asked to enact safety laws providing for the safe construction and equipment of buildings, regular inspecton of conditions, and the training of employees to observe proper precautions against accidents. The statement points out that "although the U. S. Employees' Compensation Commission is now expending approximately $3,000,000 per annum to alleviate the results of industrial accidents, it has no authority to take action of a preventive nature which might obviate the necessity for this expenditure and the loss of life and limb which it connotes." The F.A.E.S. also recommends the adoption by the several states of uniform legislation, and will support the plan of the National Safety Council for Conservation Week.

Concerning the registration of engineers it was resolved that "American Engineering Council should continue to collect and keep up to date a record of the Engineers' Registration and Licensing Laws that may be proposed or passed, together with decisions thereunder, for the use of the constituent societies of the F.A.E.S. and others, but that it assumes no control over the actions of such constituent societies in regard thereto."

The Board also voted to study the question of constituting the American Engineering Council a clearing house on elimination of waste, to endorse the plan for Government reorganization, to broaden the program of its Reforestation Committee, and to further American participation in the proposed world power conference in London in 1924.

Report of the Secretary

Secretary Wallace presented a detailed report, an interesting feature of which was a résumé of services rendered by the F.A.E.S. to various engineering societies, groups of engineers, organizations, and individuals during recent weeks. It has supplied information on the formation of engineering organizations, secured speakers for different groups, suggested men for important engineering positions, and provided full information on registration of engineers, uniform traffic regulation, provisions for housing workers, and other matters of importance.

He announced that the report on the Elimination of Waste in Industry is to be published in German by the Masaryk Academy of Czechslovakia, which is a government agency, and circulated in Czechoslovakia, Austria, and Germany, and quoted the president of the Academy as stating that the report is "one of those very few real contributions toward reconstruction of the postwar world."

Engineering and Industrial Standardization

Voluntary Adoption of Standards of Quality[1]

AMONG numerous topics of interest to the manufacturers and merchants of the United States contained in the Annual Report of Secretary of Commerce Hoover for the year 1922, there is one to which I particularly desire to invite your attention. Under the heading Voluntary Establishment of Grades and Qualities, Secretary Hoover has the following to say:

Agitation has been current for many years for the extension of the Federal laws to the establishment of grades and qualities of different commodities. The lack of such established grades and standards of quality adds very largely to the cost of distribution because of the necessity of buying and selling upon sample or otherwise, and because of the risk of fraud and misrepresentation, and consequently the larger margins in trading. It was considered by the department, however, that it would be infinitely better if such grades and qualities could be established voluntarily in the trades themselves instead of by legislation, and policed by trade associations as in the case in several old-established trades. To this end a number of conferences have been held in different branches of the lumber, textile, paper and other trades. The service of the department has been to bring the different branches of the trade, the manufacturers, wholesalers, retailers, and representatives of larger consumers' associations together and to develop committees of different branches of trades. The plan has been generally welcomed and applications have been received from many trades for such assistance. The expert services of the Bureau of Standards, Bureau of Foreign and Domestic Commerce, and the other bureaus of the department have been brought into service for technical advice in these matters, and results of important bearing upon the improvement of business ethics and cheapening of distribution have been attained.

This topic of voluntary action of business men to establish definite grades for various lines of merchandise should be of especial interest to the organization members of the National Chamber. Shoe manufacturers, textile manufacturers, and others have been worried by snap-judgment proposals to set up so-called "pure shoe" and "pure fabric," etc., standards by Government action. Of course, the reputable American business man is not afraid or unwilling to sell his goods on reasonably drawn specifications or to stand back of the quality of his product to a reasonable extent. There is nobody better qualified to pass on what is and what is not reasonable as a standard of quality or performance than those who are in the trade itself. Here, as Secretary Hoover points out, is undoubtedly a field for voluntary action on the part of producers, manufacturers, and merchants in establishing grades and setting standards of quality or performance, with which the consumers will be sympathetic.

Business is facilitated and the ground for commercial disputes between buyer and seller is narrowed down if sales are made on the basis of standard grades of merchandise, perfectly familiar to both buyer and seller. In a good many foreign countries there has been loss of good will for particular American dealers as well as some lingering prejudice to the good name of American business generally, which can be traced to the lack of understanding and agreement between buyer and seller as to the qualities entering into transactions, or to the absence of standards of quality and performance. When such standards exist, backed up by the moral force of a trade association or trade group in the United States, the promotion of the sale of American merchandise of a given kind and the building of good will toward American trade abroad are made easier, and rest upon a sound foundation.

Standardization, and the setting up of systems of inspection and certification in some cases, have made most progress among lines of raw material and foodstuffs sold in bulk and moved in large amounts. The full possibilities of doing business on standards of quality have not yet been realized, even in many such lines of merchandise. It is, of course, not only in the foreign trade, but in the whole wide range of domestic trade that the use of clear standards, easily checked up, may be developed. The American Society for Testing Materials, and many other organizations represented in the American Engineering Standards Committee are making great progress in setting up and improving national standards on engineering products. The applicability of the same principles to numerous lines of manufactured specialties is well worthy of consideration by trade associations and chambers of commerce.

Some commercial and trade associations not only set up standards but go further and provide rules and facilities for inspection and certification of merchandise. Costs must be kept down. With all due recognition of this fact, however, where actual inspection and certification of individual shipments do not add disproportionately to the costs of merchandise, and do serve a useful purpose, associations may well consider the possible desirability of making some arrangements, either with existing bureaus, laboratories, or other agencies doing commercial work of sampling, inspecting, testing, and certifying, or of actually setting up such accommodations if they do not exist adequately for the needs of the particular industries as those needs grow.

Our department managers in the different departments of the staff of the Chamber of Commerce of the United States are desirous of coöperating with any organization undertaking or extending this class of work. We have been in touch with some of the organizations that have gone far in this direction. The book of rules for trading in all sorts of oil products, adopted by the Interstate Cotton Seed Crushers Association may be cited as an example of association work on definitions of grade and quality, sampling, testing, fixing variation, performance of contract, etc., which would probably be a revelation to those not in the trade. We want more information concerning the extent to which other associations have gone to date in the adoption of voluntary standards and the enforcement of those standards. And, further, we want an indication from our members as to the ways in which our Natural Resources Production Department, our Fabricated Production Department, our Domestic Distribution Department, our Foreign Commerce Department, or the departments dealing with insurance, finance, and transportation can be of assistance in furthering this movement. We are in touch with the Government bureaus chiefly concerned and are working directly with some national organizations in getting their standards known in foreign countries.

[1] From an open letter to American business men by Julius H. Barnes, President, Chamber of Commerce of the U. S.

Report of the Director, Bureau of Standards

THE 1922 Report of the Director of the Bureau of Standards which has been recently made available in pamphlet form ($5^3/_4$ by 9 in., 282 pages) contains much of interest to engineers whether they are engaged in manufacturing, sales, or pure engineering. The following paragraphs taken from the early pages of the report will serve to emphasize the important service which the Bureau of Standards is able and anxious to render to the public and to industry.

The bureau compares with its own standards of measurement the standards and measuring instruments of states, cities, scientific laboratories, educational institutions, and the public. In this way the standards of the National Government are made available to every one in the country. For these comparisons a nominal fee is charged, except in the case of national and state government institutions. The bureau is at all times glad to assist these institutions in matters concerning these standards or their use, whether it be in connection with the enactment of laws, regulations, or ordinances concerning the weights and measures of every-day trade or in connection with precision standards used in scientific work.

It must not be inferred from the above that the bureau's activities are devoted principally to the interests of the user or consumer. The fundamental facts regarding standards of measurement, quality, or performance are the very things which most deeply concern manufacturers; they are fundamentally concerned, either directly or indirectly, with the improvement of methods of production or the quality of the output. It may be said that the bureau occupies somewhat the same position with respect to the manufacturing interests of this country that the bureaus of the Department of Agriculture do to the agricultural interests. Many industries realize the importance of scientific investigation which, in practically every case, involve some kind of precision measurement.

During the past year the bureau has continued its close coöperation with American industries. It has continued to act as a clearing house for fundamental, scientific, and technical information, and manufacturers are coming to realize more and more that they can often secure from the bureau general and sometimes even specific advice concerning improvements in their particular industrial processes. The solution of many difficult problems in the industries cannot be reached in commercial plants, but requires the work of a specially equipped research laboratory, working always in close coöperation with manufacturers who are the best judges of the practical aspects of the problem.

One of the greatest services which the bureau performs for the industries is the training of men for scientific and technical research work. Many young men receive what is, in some respects, better than a postgraduate

course by working in some of the minor scientific positions at the bureau during the years immediately following the completion of their college course. These men then go into the industries with a better conception of the problems of research work.

National Conference Votes for Safety Code on Walkway Surfaces

A CONFERENCE attended by sixty-three representatives of trade associations, technical societies, safety organizations, and Government departments, held in New York recently, declared by unanimous vote that "It is desirable to have a nationally uniform safety code on walkway surfaces" and that the development of this code should be carried out under the procedure of the American Engineering Standards Committee.

The conference voted to include in the code elevator floors, elevator landings, corridor floors, ramps, runway floors, stair treads and landings, fire-escape treads and landings, floors around machinery and at door thresholds, and sidewalk hazards such as coal-hole covers and sidewalk doors. It was recommended that the sectional committee consider the question of platforms in front of electrical apparatus, especially switchboards and floors around machinery in motion, as to insulation and non-slip qualities. This new code will apply to apartment houses, factories, and other working places, office buildings, hospitals, hotels, and restaurants, railway cars, railway stations and train platforms, schools and theaters.

At a meeting of the Main Committee of the A.E.S.C. held since this conference the American Institute of Architects and the American Society of Safety Engineers were designated as joint sponsors for this project. These sponsors will organize the sectional committee which will draft the code. This sectional committee as usual will be composed of official representatives of all organizations concerned with the subject of safe walkway surfaces, either as producers, consumers, casualty underwriters, or governmental officials representing the general public.

Protection of Heads and Eyes

A SECOND edition of the National Safety Code for the Protection of the Heads and Eyes of Industrial Workers has been issued in pamphlet form. The arrangement of the code is such as to first present the general requirements, including a classification of the occupations which require eye protection. Then follow the detailed requirements for each group of occupations, operating rules, and finally the specifications for tests which must be met to insure that protectors will adequately fulfil their purpose.

Following is a discussion of the rules intended to assist the reader in understanding the reasons for the rules and in interpreting the rules, and to give suggestions for the best means of carrying them out.

E.I.C. Elects Successor to President St. Laurent, Who Recently Died

WALTER J. FRANCIS, consulting engineer of Montreal and senior vice-president of the Engineering Institute of Canada, has been elected president to fill the unexpired term of Arthur St. Laurent, who died early in March. Mr. St. Laurent, who assumed office in January, was born in Rimouski, Quebec, in 1859. He was graduated from Montreal University, and in 1888 entered the service of the Public Works Department of Canada, remaining in government service all his life and rising to the position of chief engineer of the department. Among the operations over which he had charge was the construction of the dam at St. Andrews Rapids on the Red River; the building of a traffic bridge across the North Saskatchewan River at Edmonton, where he introduced concrete in bridge construction; the lengthening of the dry dock at Levis, Quebec; and the construction of the Laurier bridge at Ottawa and the grain elevator No. 1 at Montreal Harbor.

Mr. St. Laurent's successor is a graduate of the University of Toronto. He was engineer for the royal commission of inquiry into the Quebec bridge disaster and reported on the wreck, developing in detail the theory for the collapse. His consulting work has included designs and reports on many hydroelectric and steam power plants, investigations and reports on buildings, especially foundations, and municipal investigations.

Facts Favoring Railway Electrification

MANY articles have been written comparing steam and electric motive power for railroads. Generally they state that electric power permits more rapid acceleration, that stand-by losses are reduced or eliminated, large overloads can be handled for short periods, smoke is eliminated, coal and water stations are not needed, locomotive coal need not be hauled, less coal is used, etc. On the other hand it is shown that when steam power is used, intricate and interdependent power-distribution facilities are not required, capital expenditures are reduced, no trouble is caused by inductive interference or electrolysis, and so on. All these statements are generally accepted as facts, but it is unfortunate that most of them of necessity are qualitative rather than quantitative. For example, it is variously estimated that electric operation will save all the way from 10 to 70 per cent of the annual coal bill. Actual figures in one case indicate the saving to be 28 per cent, but even these figures are open to criticism. It is for this reason that we welcome such facts as the following: Electric locomotives on the Chicago, Milwaukee & St. Paul are used to haul trains on continuous runs of 440 miles except for station stops; switching locomotives on the New York, New Haven & Hartford are kept in continuous service 24 hours a day for more than 70 per cent of the total time without being shopped for even minor repairs, while road engines frequently make 500 miles a day and average 33,000 miles per locomotive failure; multiple-unit cars on the Pennsylvania operate with an average of over 48,000 car-miles per detention. A recently issued statement also announces that several of the 41 passenger locomotives which have been in service for 16 years have now been run more than 1,000,000 miles. Facts like these do two things; establish the dependability of electric equipment and make easier the decision of the road wishing to determine whether or not it should adopt electric operation. (*Railway Age*, Mar. 24, 1923, p. 795)

Civil Engineers Vote Against Joining Federation

A BALLOT of the membership of the American Society of Civil Engineers on joining The Federated American Engineering Societies, canvassed on April 6, 1923, showed a total vote of 5753, of which 3641 were opposed to joining the Federation. The results of the ballot, tabulated by districts, are as follows:

	District	Yes	No
1	Foreign	25	84
	Territory within 50 mi of N. Y. Postoffice	166	688
2	New England, New Brunswick, and Nova Scotia	84	331
3	New York (except as included in District 1) and Quebec	107	221
4	Eastern Pennsylvania, New Jersey (except as included in District 1), and Delaware	143	292
5	District of Columbia, Maryland, and Virginia	134	254
6	Western Pennsylvania, West Virginia, and Ontario	87	214
7	Michigan, Wisconsin, Iowa, Minnesota, Manitoba, North and South Dakota	276	144
8	Illinois	167	186
9	Indiana, Kentucky, and Ohio	184	154
10	Alabama, Florida, Georgia, Mississippi, North and South Carolina, and Tennessee	109	203
11	Colorado, New Mexico, Arizona, Southern California, Utah, and Wyoming	191	189
12	Idaho, Montana, Washington, Oregon, Alaska, Alberta, British Columbia, Saskatchewan, and Yukon Territory	102	124
13	Northern California and Nevada	84	209
14	Missouri, Arkansas, and Louisiana	108	158
15	Nebraska, Kansas, Oklahoma, Texas, and Mexico	145	200
		2112	3641

The Efficiency of The Scotch Marine Boiler

THE captions for Figs. 7 and 8 in Mr. Jefferson's paper on The Efficiency of the Scotch Marine Boiler, published in the April issue of MECHANICAL ENGINEERING, were, through error, interchanged. The higher-efficiency curve is for the forced-draft test, while the lower values are for the induced-draft test. Photographs of all the burners used in the test were submitted with the original article. The selection of illustrations was made by the Editor.

Meetings of Other Societies

American Railway Engineering Association

Standardization and labor economics were leading topics under discussion at the twenty-fourth annual meeting of the American Railway Engineering Association held in Chicago, March 13–15, 1923. J. L. Campbell, of the El Paso & Southwestern Ry., in his address as retiring president of the association, spoke at some length upon the problem of labor economics, and in regard to standardization emphasized the need of a wider use of adopted standards of design and practice. Both he and R. H. Aishton, president of the American Railway Association, called attention to the large amount of standardization work essential in railway engineering. The Committee on Standardization recommended close coöperation with the work of the American Engineering Standards Committee. The matter was discussed by many of those present but no definite action was taken. The Association is at present represented on the A.E.S.C. by one member, through the American Railway Association.

The Committee on Economics of Labor considered the problems of obtaining and retaining labor, and organizing labor for efficient and economical work. This committee is considering methods of organizing forces for maintenance work and submitted a report of preliminary studies outlining methods of renewing rails and ties.

The Rail Committee presented statistics of rail failures, revealing a deterioration of quality of rail in the 1916 and 1917 rollings. The number of failures per 100 track-miles during five years' service ranged above 200 for the rails rolled about 1910, while subsequent improvement of quality brought the failures of 1914 rail down to 74. The latter figure increased to 105 for 1916 rail. Preliminary service indications for the rollings of 1918 and subsequent years indicate renewed improvements.

Final specifications for the erection of railway bridges were presented and adopted, and highway-bridge specifications for bridges less than 300 ft. span were presented.

Following a discussion of the need for participation by engineers in the revision of the Interstate Commerce Commission's schedule of accounts for railways, it was voted that the association, in connection with the American Railway Association, take prompt action to bring the engineering requirements of an accounts schedule to the attention of the commission.

The Committee on Water Service discussed the relative merits of cast iron, steel, wood, and other materials for pipe lines, the Committee on Yards and Terminals presented a comprehensive study of the principles affecting the design of passenger stations for main-line traffic, and other committees gave reports on additional phases of railway engineering.

Edward H. Lee, president and chief engineer, Chicago & Western Indiana R. R., was elected president for 1923–1924. E. H. Fritch was reëlected secretary.

American Management Association

A conference of nearly two hundred executives, representing industrial and commercial enterprises in all parts of the country, was held in New York on March 14, 1923, to organize the American Management Association. This new organization takes the place of the National Personnel Association, which was formed last year through the merger of the National Association of Corporation Training and the Industrial Relations Association of America. It will be devoted exclusively to the consideration of the human factor in commerce and industry.

Among the speakers at the meeting were Charles R. Hook, vice-president and general manager of the American Rolling Mill Co., Middletown, Ohio, and Howard Coonley, President of the Walworth Manufacturing Co. Mr. Hook stressed the necessity of close and friendly coöperation between the heads of industrial enterprises and the workers in order that better conditions, social and economic, may be brought about. He stated that the problem of industrial America is not just more production, but more units of production per man per day. One part of the problem, he continued, deals with improved machinery to reduce the number of men needed per unit of product and the other affects individual efficiency and reward. Mr. Coonley discussed the correlation of sales and production.

The officers of the new association are: President, W. W. Kincaid, president of the Spirella Co., Niagara Falls, N. Y.; Vice-Presidents; Sam A. Lewisohn, New York, vice-president of the Miami Copper Company, John A. Stevenson, vice-president of the Equitable Life Assurance Society of the United States, New York, and Fred W. Tasney, vice-president of the Prudential Insurance Company of America, Newark, N. J. Mr. Lewisohn, who presided at the business meeting, issued a statement in behalf of the officers and directors of the association, as follows:

> Personnel work is an integral, inseparable part of management interwoven into all of the efforts and activities of the production and sales departments and of the office. It cannot be segregated as an isolated function, and all efforts to bring about such a separation are foredoomed to failure. There is ample experience to prove this sweeping statement.
>
> This meeting was designed to present to executives two important phases of the problem in which the Association is interested. It is believed that the consideration of the human side of management as an integral part of the whole will lead to a more permanent acceptance of the idea. Incidentally it will provide greater opportunity for the personnel man and an increasingly complete interpretation of the management problem with adequate recognition to the most important factor—the human factor—in commerce and industry.

American Boiler Manufacturers' Association

The American Boiler Manufacturers' Association held its winter meeting in New York on Feb. 12, 1923. Following an address by the president, A. G. Pratt, vice-president of the Babcock & Wilcox Co., E. R. Fish, representative of the association on the A.S.M.E. Boiler Code Committee, reported progress in the work of that committee, and a letter from Charles E. Gorton, chairman of the Uniform Boiler Law Society, reporting the progress of boiler legislation in several states, was read.

Papers on Budgeting, by G. S. Barnum, of the Bigelow Co., and on the Standardization of Bolt, Nut, and Rivet Proportions, by F. G. Cox, weer presented. Mr. Barnum's paper emphasized the value of an accurate method of cost accounting to the manufacturer.

W. C. Connelly presented the report of the Committee on Related Industries, and summarized the replies to a questionnaire on boiler rating which had been sent out to the entire membership of the association. About 45 replies were received; of these 7 preferred to rate the boilers by horsepower, 24 by square feet of heating surface, and 11 by both heating surface and horsepower. The manufacturers of water-tube boilers were the only ones to present a unity of opinion on the use of 10 sq. ft. per hp.; the others varied from 7.5 to 12, the greatest difference being in the small sizes of locomotive and vertical-type boilers. On the question of including integral economizer surface as part of the boiler heating surface, 19 firms favored treating this as a separate item, while 4 considered that it should be treated as boiler heating surface.

Reports on a conference with the Department of Commerce on Standardization and Simplification, and on the work of the National Board of Boiler and Pressure Vessel Inspectors were also presented.

American Chemical Society

The 65th meeting of the American Chemical Society was held at New Haven, Conn., during the week of April 2, 1923. Sessions were held by all the divisions and sections except the leather and fertilizer divisions. The papers presented numbered over 350, and covered such subjects as agricultural and food chemistry; petroleum, gas, and fuel chemistry; motor fuels; industrial and engineering chemistry; cellulose chemistry; rubber chemistry; chemical education; history of chemistry; biological chemistry; sugar chemistry; physical, inorganic, organic, and dye chemistry; water, sewage and sanitation; and the chemistry of medicinal products.

Historical, educational, and industrial exhibits were given, and inspection trips made to a number of manufacturing plants in New Haven and neighboring cities, and to various laboratories at Yale University. One day was devoted to the dedication of the Sterling Chemistry Laboratory.

Speakers at general meetings included James R. Angell, president of Yale, Brigadier General Amos A. Fries, Chemical Warfare Service, U. S. War Department, Arthur D. Little, Boston, Mass., Francis P. Garvan, president of the Chemical Foundation, and Sir J. J. Thomson, F.R.S.

LIBRARY NOTES AND BOOK REVIEWS

Accurate Tool Work. By C. L. Goodrich and F. A. Stanley. Second edition. McGraw-Hill Book Co., New York and London, 1923. Cloth, 6 × 9 in., 300 pp., illus., diagrams, $3.

A collection of articles written by the authors or selected from the *American Machinist*, which discuss practically, methods and devices for producing accurate, interchangeable machine parts.

Briquetting. By Albert L. Stillman. Chemical Publishing Co., Easton, Pa., 1923. Cloth, 6 × 9 in., 466 pp., illus., $6.

This is the first American work on the subject of briquetting, and is based, the author states, on many years' experience. The book opens with an account of the raw materials, which is followed by a chapter on briquet presses. Succeeding chapters describe the methods for briquetting various materials, such as steel swarf and turnings, cast-iron borings, non-ferrous metals, wood waste, peat, lignite, coals, flue dusts and ores. Binders are also discussed. Bibliographies and lists of patents on each subject are given.

Car Builders' Cyclopedia. 1922. Tenth edition. Locomotive Cyclopedia. 1922. Sixth edition. Simmons-Boardman Publishing Co., New York, 1922. Cloth, 9 × 12 in., nearly 1200 pp. a vol., illus., diagrams, $8 per vol.

These two works have long been valued for the definite, thorough description of current American practice in the construction and repair of railroad rolling stock which they present. Each opens with a dictionary of the terms used, following this by a series of chapters which present drawings and photographs of contemporary equipment of all kinds, with brief descriptive articles on development and present practice. Specifications of the American Railway Association, Government regulations and safety rules are given.

The present editions offer the text in a new arrangement, by which the information on each broad topic is collected in one chapter instead of being scattered through the book under specific headings as in previous editions. The new arrangement will, it is thought, facilitate reference to the books.

Design of Machine Elements. By James A. Mease and George F. Nordenholt. First edition. McGraw-Hill Book Co., New York and London, 1923. Cloth, 6 × 9 in., 237 pp., diagrams, tables, $2.50.

Most textbooks on this subject are too comprehensive, in the opinion of the authors of this one, to be suitable for an elementary course. To overcome this difficulty they present the present text which makes no claim to originality of subject-matter except in the methods of computing gear pitches, but which is new in scope and in its manner of presentation. The book is the outgrowth of notes originally prepared by Prof. P. B. de Schweinitz for use at Lehigh University.

Design of Steam Boilers and Pressure Vessels. By George B. Haven and George W. Swett. Second edition. John Wiley & Sons, New York; Chapman & Hall, London, 1923. Cloth, 6 × 9 in., 435 pp., illus., diagrams, charts, tables, $4.

This book is intended primarily to teach rational methods of boiler design, while at the same time it is intended to be an introduction to the study of machine design, a purpose for which the authors believe an analysis of the stresses existing in boilers and other pressure vessels has many advantages.

In general, the results here presented have been obtained by rational rather than empirical methods, the usages of current boiler-making practice having been kept constantly in view. Many graphs and tables are given which enable numerical results to be obtained without using formulas. The principles are illustrated by their application to the complete practical design of boilers and tanks of six different types.

Dictionary of Applied Physics. Vol. 3, Meteorology, Metrology and Measuring Apparatus. By Sir Richard Glazebrook. Macmillan & Co., New York and London, 1923. Cloth, 6 × 9 in., 839 pp., illus., 63s.

The third volume of this dictionary maintains the high standard of excellence shown in the first two volumes. It should be of interest to engineers in all branches of the profession, as it contains accurate scientific data and precise theoretical information on measuring instruments and methods of measurement. Among the important articles are: Surveying Tapes and Wires, by Sidney W. Attwell; Preparation of Quartz Fibers, by Charles V. Boys; Nomography, by Selig Brodetsky; Physics of the Atmosphere, by David Brunt; Measurement of Solar Radiation, by William W. Coblentz; Watches and Chronometers, by E. G. Constable; Design of Scientific Instruments, by Horace Darwin and Cecil C. Mason; Balances, by F. A. Gould; Meters, by Edgar A. Griffiths; Calculating Machines, by Ellice M. Horsburgh; Comparators and Line Standards of Length, by W. H. Johnson; Combination of Observations, by H. L. Jolly; Mechanical Means of Integration, by Hyman Levy; Weighing Machines, by George A. Owen; Gauges, by Frederick H. Rolt; Clocks and Time-keeping, by Ralph A. Sampson; Metrology, by John E. Sears, Jr.; Humidity, by Sydney Skinner; Draughting Devices, by Alma Turner; Micrometers, by H. H. Turner; and Atmospheric Electricity, by C. T. R. Wilson. Ample cross-references and a good index are provided, and there are numerous references to other literature on many subjects.

Dimensional Analysis. By P. W. Bridgman. Yale University Press, New Haven, 1922. Cloth, 6 × 9 in., 112 pp., $5.

The substance of this book was given as a series of lectures to the Graduate Conference in Physics of Harvard University in 1920. The growing use of the methods of dimensional analysis in technical physics, as well as the importance of the method in theoretical physics, make it desirable that every physicist should have it at his command. Professor Bridgman's statement of principles is accompanied by many illustrations of their applications, especially chosen to emphasize the points concerning which there is the most common misunderstanding. Some of these deal with important questions of electrical theory, aeronautics, and other subjects of interest to engineers.

Drop Forging and Drop Stamping. By Henry Hayes. Isaac Pitman & Sons, New York and London, 1923. (Pitman's Technical Primers.) Cloth, 4 × 6 in., 108 pp., illus., $0.85.

In previous books on drop forging, attention has generally been concentrated upon a description of the plant used. A broader treatment has been attempted in this volume, particularly with a view to relating the mechanical with the metallurgical problems. The aim has been to provide an introduction to the equipment and methods of the drop-forge shop, to the principles underlying drop forging and to the heat treatment and hammer treatment of forgings. The question of dies is also discussed.

Electricity in Agriculture. By Arthur H. Allen. Isaac Pitman & Sons, London and New York, 1922. (Pitman's Technical Primers.) Cloth, 4 × 6 in., 117 pp., illus , tables, $0.85.

A small book indicating briefly the various ways in which electricity can be used by the farmer for light and power purposes and for electroculture, and the methods by which he can avail himself of electricity. The book also calls to the attention of central-station managers the possibilities of the farmer as a customer. Written for British farmers, it treats the questions in the light of British conditions.

Eleménts de Mécanique, A L'Usage des Ingénieurs; Statique Cinématique. By Robert d'Adhémar. Gauthier-Villars et Cie, Paris, 1923. Paper, 6 × 10 in., 254 pp., 16 fr.

This textbook reproduces the course of instruction given by the author at the Institut Industriel du Nord de la France. It contains the elements of kinematics and dynamics, and an elementary development of statics.

Engineering Economics. By John C. L. Fish. Second edition. McGraw-Hill Book Co., New York and London, 1923. Cloth, 6 × 9 in., 311 pp., tables, $3.

This book treats of the principles which underlie economic judgment in the business side of engineering. The present edition, which is practically a new text, assumes choice of investment to

be the fundamental problem of engineering economics and proceeds to the analysis of this problem in a way that will give the student a working knowledge of the principles involved.

Engineering of Excavation. By George B. Massey. John Wiley & Sons, New York; Chapman & Hall, London, 1923. Cloth, 6 × 9 in., 376 pp., illus., diagrams, tables, $6.

The writer of this treatise, after spending practically all of his time since 1899 in the study of excavating problems and the application of machinery to them, has brought together the fruits of his experience. The book describes present methods of excavating and the machines and other equipment used in excavating and transporting both on land and under water. Capacities are given and the machines which are best suited for various kinds of work are indicated.

Gasmaschinen und Ölmaschinen. Vol. 1. By Alfred Kirschke. Vereinigung Wissenschaftlicher Verleger (Walter de Gruyter & Co.), Berlin and Leipzig. 1922. Boards, 4 × 6 in., 133 pp., illus., diagrams, $0.30.

This is the first of two small volumes, adapted to the pocket, in which are given a concise account of the origin and development of the internal-combustion engine. The present volume treats of small gas and oil engines. Chapters are devoted to gas as a source of power, early gas engines, cycles, general design and construction, valve gears, ignition and regulation, oil and spirit engines, automobile, airship and boat engines, gas producers, cost of operation, and gas and steam engines.

Hendricks' Commercial Register. 1923. S. E. Hendricks Co., Inc., New York, 1922. Cloth, 8 × 11 in., 2320 pp., $15.

Hendricks' Commercial Register endeavors to list all producers, manufacturers, dealers, and consumers connected with the engineering, chemical, metallurgical, railroad, contracting, and allied industries. It provides a ready directory to the manufacturers of an article and to the location of any firm. It also furnishes an index to trade names, enabling the manufacturer of any named article to be found. Over eighty thousand firms are listed in the 1923 edition.

Labor and Democracy. By William L. Huggins. Macmillan Co., New York, 1922. Cloth, 5 × 8 in , 213 pp., $1 25.

This volume, by the presiding judge of the Kansas Court of Industrial Relations, is a discussion of the relations between government and modern industrial conditions. The author endeavors to point out some of the dangers to democratic institutions inherent in the labor movement of today, to appraise the rights of labor, of capital, and of the public, to suggest legal principles upon which remedial legislation may be based, and to give the first results of the Kansas experiment in adjudicating industrial disputes.

Lehrbuch der Eisen- und Stahlgiesserei. By Bernhard Osann. Fifth edition. Wilhelm Engelmann, Leipzig, 1922. Cloth, 7 × 10 in., 693 pp., illus., diagrams, 24 mks.

This textbook of foundry is intended for beginners in the industry and also as a reference work for those engaged in iron and steel founding.

A concise but comprehensive account of the methods and appliances used is given, which is supplemented by numerous references to the literature and drawings. Special attention is given to molding methods, materials and machines. Chapters on steel and malleable castings are included. The volume concludes with a chapter on the metallography of cast iron.

Les Marées et leur Utilisation Industrielle. By E. Fichot. Gauthier-Villars et Cie., Paris, 1923. (Science et Civilisation.) Paper, 5 × 8 in., 254 pp., 9 fr.

The work of a chief hydrographic engineer of the French navy, this volume is a study of the possibility of using the energy of waves, on a large scale, as a source of industrial power. The author describes the action of the heavenly bodies on the waters of the ocean, the undulatory movements of the ocean, and the formation and propagation of waves. This study of the theory of waves is followed by an exposition of the projects intended to utilize the waves as a source of power. The book is intended not only for specialists, but also for legislators and others interested in economic problems.

Meaning of Relativity. By Albert Einstein. Princeton University Press, Princeton, 1923. Cloth, 5 × 7 in., 123 pp., $2.

This volume presents, in a translation by Prof. Edwin Plimpton Adams, four lectures delivered by Doctor Einstein at Princeton University, during May, 1921. The first lecture is upon space and time in pre-relativity physics; the second upon the theory of special relativity; and the remaining two upon the general theory of Relativity.

Machine Tools and Their Operation. By Fred H. Colvin and Frank A. Stanley. McGraw-Hill Book Co., New York and London, 1922. Cloth, 6 × 9 in., 2 vols., illus., diagrams, tables, $8.

This textbook is intended to give the mechanic an understanding of the principles involved in the operation of the ordinary machine tools, and thus enable him to adapt them to the various jobs that occur in the shop. Special attention is given to such subjects as cutting speed, clearance, angles, chip clearance, lubrication, speed and feed, and tool supports. The language is clear, simple and non-mathematical.

Metals and Their Alloys. By Charles Vickers. Henry Carey Baird & Co., New York, 1923. Cloth, 6 × 9 in., 767 pp., illus., tables, $7.50.

This work is based on Brannt's well-known work, Metallic Alloys, but the text has been so enlarged and so thoroughly revised that a new book has resulted. The book is intended to furnish modern, practical information on the composition and properties of industrial metals and their alloys, and on their manufacture, casting and working. The needs of the foundryman have been kept especially in view.

Modern Motor Car Practice. Edited by W. H. Berry. Henry Frowde & Hodder & Stoughton, London, 1921. (Oxford technical publications.) Cloth, 6 × 9 in., 582 pp., illus., $10.50.

This work, the result of the collaboration of a number of prominent English authorities on automobile engineering, is a valuable record of contemporary motor-car practice. An account is given of present methods of design and construction of each part of the automobile, with some review of the way in which present forms have developed, of the advantages and disadvantages of various designs, and of the trend of future change. Written in an interesting style and well illustrated, the book should prove of use to designers and manufacturers, and also to owners.

Practical Factory Administration. By Matthew Porosky. First edition. McGraw-Hill Book Co., New York and London, 1923. Cloth, 5 × 8 in., 244 pp., diagrams, $2.50.

The purpose of this book is to present the accepted principles of modern factory administration and to show how they may be effectively applied to actual operating conditions. It is addressed to executives, salesmen, cost accountants, and students of industrial administration. The principles, practices, and forms that it gives are presented from the point of view of the average rather than the exceptionally large establishment.

Principles of Electric Spark Ignition in Internal Combustion Engines. By J. D. Morgan. Crosby Lockwood & Son, London; D. Van Nostrand Co., New York, 1922. Cloth, 6 × 9 in., 94 pp., diagrams, $2.25.

In this little book an account is given of the scientific basis of electric spark ignition. During recent years much research has been undertaken on ignition problems, the main results of which, so far as they are of direct value to designers and students of gasoline engines, are here brought together. The design and constructional details of ignition apparatus have been excluded from this discussion.

Principle of Relativity with Applications to Physical Science. By A. N. Whitehead. University Press, Cambridge, 1922. Cloth, 6 × 9 in., 190 pp., 10s. 6d.

This book is not an attempt to expound Einstein's theory, but to set forth an alternative theory of relativity and to show the results deducible from the application of the formulas assumed for the gravitational and electromagnetic fields. Dr. Whitehead believes that our experience requires and exhibits a basis of uniformity, and that in the case of nature this basis exhibits itself as the uniformity of spatio-temporal relations; a conclusion that entirely

cuts away the casual heterogeneity of these relations which is the essential of Einstein's later theory. This uniformity is essential to the outlook of the author. He finally arrives at metrical formulas identical with those of Einstein's earlier theory, but with entirely different meanings ascribed to the algebraic symbols.

Problems in Machine Design. By O. A. Leutwiler. First edition. McGraw-Hill Book Co., New York and London, 1923. Cloth, 6 × 9 in., 133 pp., diagrams, tables, $1.50.

A series of isolated problems covering the various parts of the subject of machine design, intended to supplement those given in textbooks on that subject, and thus to give the student greater familiarity with the application of theory and a better working knowledge of the subject. Almost all the problems have been taken directly from existing machines, so that the student works with actual engineering information.

Seagoing and Other Concrete Ships. By N. K. Fougner. Henry Frowde and Hodder & Stoughton, London, 1922. (Oxford technical publications.) Cloth, 6 × 10 in., 216 pp., illus., diagrams, 10. $7.

The aim of the author is to present a true record of the principal seagoing concrete ships actually built up to the present, and to analyze the merits of these ships in comparison with ships built of wood and steel. The main part of this book is based on personal experience gained in the construction of about thirty vessels of concrete during the past five years. Information about ships built by others has been obtained partly through correspondence with the designers, builders or owners, and partly from the engineering press.

Standard Inventory Manual. By Frederic W. Kilduff. First edition. Accounting Standards Corporation, Chicago, 1922. Cloth, 6×9 in., 227 pp., charts, tables.

A reference book for managers of industrial enterprises, based on the practice of well known firms. Intended to assist him to prepare an inventory manual for his own firm which will contain complete, detailed rules for planning, preparing, taking, pricing and tabulating inventories with the least possible expense and loss of time.

Steam-Turbine Principles and Practice. By Terrell Croft. First edition. McGraw-Hill Book Co., New York aud London, 1923. (Power Plant Series.) Cloth, 6 × 8 in., 347 pp., illus., $3.

Intended to provide the operating engineer and the plant superintendent with information reqnired in every-day work. The topics treated are (1) those with which he must be familiar to insure the successful, economical operation of turbines, and (2) those which he must know in order to choose the proper turbines for any class of work. Design is not treated. The book is a clearly written account of steam turbines, written for the user, not for the designer or maker.

Structural Drafting and the Design of Details. By Carlton Thomas Bishop. Second edition. John Wiley & Sons, New York, 1922. Cloth 8 × 11 in., 352 pp., diagrams, tables. $5.

This book for students and structural draftsmen corresponds in scope to the duties of the structural steel draftsman, and therefore covers not only the preparation of the detailed workings drawing for steel structures, but also the design of the details of construction. It is a textbook in structural drafting and may be used as a textbook in elementary structural design. The new edition has been prepared to meet the extensive changes in the standards of the Association of American Steel Manufacturers. At the same time other changes and corrections have been made.

Tables Annuelles de Constantes et Données Numeriques de Chimie, de Physique et de Technologie. Vol. 4, 1913–1916. Two parts. Gauthier-Villars et Cie, Paris; Cambridge University Press, Cambridge, Eng.; University of Chicago Press, Chicago, 1922. Cloth, 9 × 11 in., 1377 pp., $13.57.

The annual tables of chemical, physical and technical constants and numerical data are prepared under the direction of the International Research Council and the International Union of Pure and Applied Chemistry, by an international committee. The aim of its editors is to summarize and present in convenient form for reference the data in its field which appear in the important periodicals and treatises of each year, and thus supply investigators with the latest results of research.

Volumes 1 to 3, issued in 1912, 1913 and 1914, covered the literature of 1910–1912. Volume 4, just published, covers that from 1913 to 1916 inclusive. Full references to sources of data are given.

Tool Engineering, Fixtures for Turning, Boring and Grinding. By Albert A. Dowd and F. W. Curtis. McGraw-Hill Book Co., New York and London, 1923. Cloth, 6 × 9 in., 340 pp., diagrams, $3.50.

The first volume of this series dealt with the design of jigs and fixtures. The present volume discusses the factors that affect the design of tools and fixtures for turning, boring, and grinding. Fundamental points in design are treated and the reasons why certain things are done are explained in detail.

Technische Schwingungslehre. By Wilhelm Hort. Second edition. Julius Springer, Berlin, 1922. Cloth, 5×8 in., 828 pp., illus., diagrams, $4.80.

The author has undertaken to collect and present in systematic fashion our knowledge concerning vibratory phenomena of technical importance. The book covers the mechanics of rigid, elastic, liquid and gaseous bodies and the field of electricity. Methods for investigating these phenomena are given, with examples taken from practice. An extensive bibliography is included.

Telephony. By Samuel G. McMeen and Kempster B. Miller. American Technical Society, Chicago, 1922. Fabrikoid, 6 × 9 in., 943 pp., illus., diagram, $5.50.

A descriptive, non-mathematical work covering the entire field of telephone engineering in one volume of reasonable size. Describes the customary types of subscribers' apparatus, line systems, switchboards, automatic systems, line construction, central offices, etc. Based on American practice.

Theory of Relativity and its Influence on Scientific Thought. By Arthur S. Eddington. Clarendon Press, Oxford, 1922. (Romanes Lecture, 1922.) Paper, 6×9 in., 32 pp., $0.70.

In this pamphlet containing the Romanes Lecture for 1922, Professor Eddington gives a clear, concise account, in non-mathematical terms, of the evolution of the theory of relativity.

Treatise on Weighing Machines. By George A. Owen. Charles Griffin & Co., London, 1922. Cloth, 6 × 9 in , 202 pp., illus., diagrams, charts. $3

This book, the first English treatise on its subject, explains in simple language the principles underlying the construction of weighing machines. It is intended as a guide to the proper types for various purposes and to methods of maintaining accuracy. The basic principles of all weighing machines are included in one or another of the types described.

20th Century Guide for Diesel Operators. By Julius Rosbloom and Orville R. Sawley. Western Technical Book Co., Seattle, 1922. Cloth, 6×9 in., 637 pp., portraits, illus., diagrams, $2.50.

The authors have attempted to furnish in compact form a summary of present-day knowledge of Diesel engines and their auxiliary machinery. The information given is presented in a form suited to the needs of those in charge of power plants and covers hath land and sea operation. Many commercial types of engines are described. One chapter is devoted to low compression or "semi-Diesel" engines.

Wechselstromerzeuger. By Franz Sallinger. Vereinigung Wissenschaftlicher Verleger. Walter de Gruyter & Co., Berlin and Leipzig, 1922. Boards, 4 × 6 in., 127 pp., diagrams, $0.25.

This booklet is intended, on the one hand, as an introduction to the subject of alternating-current generators, and on the other, to give engineers without special electrical training, who are connected with the construction or operation of these machines, an understanding of their essential characteristics. A special effort has therefore been made to explain these characteristics simply and to derive the most-used formulas and diagrams.

The windings are first explained, in connection with the generation and calculation of the electromotive force and the armature fields. After the vector diagrams have been derived, the experimental proving and the method of operation are treated. In conclusion data are given on the design, calculation and construction of alternators, with examples of actual machines which show how the formulas and diagrams are used.

Monel Metal Refinery and Rolling Mill

(*Continued from page 288*)

is standard throughout, except that the housings are very heavy, weighing 12 tons each. The arrangement permits an addition of four mills on the other end of the motor drive. As there is very little fluctuation in the power required on this type of mill no flywheel has been furnished, but a motor with large starting torque is provided.

The Merchant Mills

It will be noted from Fig. 4 that in the building with the 24-in. merchant mill there are other merchant mills used for furnishing the greatly varied product in tonnages that, from a rolling-mill point of view, are small. This equipment consists of the 24-in. mill referred to previously, which not only makes sheet bar but also the various sizes of billets required, a 20-in. mill, a 14-in. mill, a 10-in. mill, and a 14-in. Belgian rougher; and the wire mill, which consists of two separate mills in line with each other, 9 in. pitch diameter, one being a five-stand roughing mill and the other a four-stand finishing mill. These mills are equipped with gears and direct motor drive and all have a flywheel on the motor-shaft speed except the 9-in. roughing mill, which due to construction difficulties has the flywheel on the mill-shaft speed. The 9-in. finishing mill drives direct without any flywheel or gear reduction.

All mills are driven by fixed-speed motors except the 10-in. mill, requiring a variation from 120 r.p.m. to about 80 r.p.m. to accommodate the varied size of material, and the 9-in. mill, the intermediate mill between the 14-in. roughing and 9-in. finishing mill, which will have a speed variation of 257 r.p.m. to 384 r.p.m., arranged in 17 intermediate steps, to accommodate the delivery speeds of the 14-in. mill.

The whole of the south side of this building is arranged with lifting doors, so that it is easy to adapt the temperature of this end to either summer or winter conditions, the same type of doors being arranged at intervals on the furnace lean-to side.

The dimensions and arrangements of the buildings are shown in Fig. 2. All of the buildings, with the exception of the office, laboratory, oil and grease house, and the electric substation, are of steel construction, the average weight per square foot of projected area being specified as 25 lb., although in some cases this is exceeded.

Wide monitors one-half the building width were adopted for the main building roof; the sawtooth roof was used for the lean-tos. These features give excellent ventilation and lighting. To assure the best working conditions during the warmer months, the prevailing winds were studied and the buildings placed accordingly.

Steel lifting doors are continuous on the sides of the refinery, hammer-shop, merchant-mill, and sheet-mill buildings. For truck or railroad entrances to buildings, rolling steel doors are provided.

The roofing and sheeting is of corrugated black sheets; the windows have wooden sash, which take up any variation in the steelwork and eliminate warping of frames which otherwise might occur. There is in all about 160,000 sq. ft. of these windows used in the entire plant. The buildings were given two coats of a noncorrosive paint and a finishing coat of battleship gray color, which gives a pleasing appearance and aids the inside lighting.

The Oil Venturi Meter

(*Continued from page 298*)

in the kinetic head and the friction loss the coefficient was computed and expressed by the formula—

$$C = 1/\sqrt{1 + (1.67/R)}$$

These coefficients were plotted on Fig. 1. This calibration applies equally well to any other size of venturi tube of the same shape. It shows that the coefficient decreases indefinitely as the slope of the lower part of the line becomes the constant 0.5. The general agreement with the experimental data for the glass model, which was of slightly different shape, shows that the assumption made in this computation was justified for low values of the turbulence but is not sufficient as the critical turbulence is approached. This is indicated by the dropping of the experimental line below the computed, and is probably due to the increased internal losses in the fluid with the higher readjustments of velocity in the cone. At low values of the turbulence the venturi tube acts merely as a resistance and is exactly as useful for the measurement of rate of flow as a piece of straight pipe with similar piezometer connections would be.

The data presented in Fig. 2 for the Simplex Standard venturi tubes are accurate to within 0.5 per cent for all values in the turbulent-flow region. This calibration is for all meters of 2:1 ratio of diameters for all sizes of tubes from 1 in. to 48 in. in diameter.

As liquids are usually transported at a much lower velocity (s) than the velocity (c) of sound in the liquid, the effect of the compressibility is negligible. The effect upon the venturi or pipeline friction-loss coefficient due to the compressibility of the liquid flowing is found to be a function of s/c by the method of dimensions. When, as is frequently the case, gases and vapors are handled at the acoustic velocity (c) or higher, the coefficients must be considered as functions of s/c as well as of Qg/du. Experimental data compiled on a graph according to this method would provide a rational calibration of venturi, orifice, and pitot meters for use with steam and high-pressure gas or air. This same method might similarly be applied to show the performance of steam-turbine nozzles and jet pumps.

The thin-plate orifice and fixed pitot-tube meters may be calibrated by the use of this same method of dimensions. The fixed pitot tube is very sensitive to irregularities of flow in the viscous-flow region, especially with heated oils; however, experimental data are necessary to determine its value and range of usefulness.

The accuracy of measurements by the venturi or thin-plate orifice meters in the viscous-flow region may be considerably affected by heated oil or by valves and fittings near the venturi tube or orifice plate, especially when the fittings are located on the upstream side. The amount of error due to these causes can only be determined by experiment.

The thin-plate orifice meter is less affected by the viscosity than the venturi meter at the lowest turbulences that are ordinarily used in practice; consequently the orifice is more suitable for use with fairly viscous liquids than is the venturi meter.

References

Model Experiments and the Forms of Empirical Equations, E. Buckingham, Trans. A.S.M.E., vol. 37(1915), p. 263.

Anomalous Results in Venturi Flume and Meter Tests, W. J. Walker, *Eng. News-Record*, May 11, 1922.

Effect of Viscosity on Orifice Flows, W. N. Bond, *Proc. Phys. Soc. of Lond.*, vol. 33, part 4, p. 225, June, 1922.

Computation of Coefficient of Discharge of Venturi Meters, W. S. Pardoe, *Eng. News-Rec.*, Sept. 25, 1919.

Measuring Flow of Fluids, J. M. Spitzglass, *Power*, Mar. 30, 1920.

Aluminum Bronze

(*Continued from page 284*)

shapes. This alloy can also be heat treated to some extent, in a manner similar to steel. By heating and quenching, its physical properties are improved to some extent, depending upon the exact composition of the material. It has been found that an addition of iron up to about 3 per cent in 8, 9, and 10 per cent aluminum bronzes improves their physical properties, workability, resistance to corrosion, etc.

The author's experience with a large variety of alloys from the manufacturing and the engineering viewpoint confirms his belief that the aluminum bronzes as a class are valuable additions to our list of engineering materials, and if he has pointed out some of the salient points, sufficient to arouse the interest of the engineer to investigate their merits further, the purpose of this paper will have been accomplished.

[In connection with the foregoing it is interesting to glance over Thomas D. West's paper on Casting Aluminum Bronze and Other Strong Metals in Vol. 8 (1887) of A.S.M.E. Transactions and one by Leonard Waldo on Aluminum Bronze Seamless Tubing in Vol. 18 (1897), both pioneer papers in presenting facts regarding this adaptable alloy.—Editor]

THE ENGINEERING INDEX

(Registered United States, Great Britain and Canada)

Exigencies of publication make it necessary to put the main body of The Engineering Index (p. 117-EI of the advertising section) into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.

AIRPLANE ENGINES

Navy Developments. Recent Developments in Aircraft Engines in the Navy, B. G. Leighton. Soc. Automotive Engrs.—Jl., vol. 12, no. 4, Apr. 1923, pp. 325–334, 12 figs. Former and present tests; progress made in development: reduction in weight; air-cooled vs. water-cooled engine; influence of power-plant weight on transportation costs.

AIRPLANE PROPELLERS

Reed One-Piece. Air Reactions to Objects Moving at Rates above the Velocity of Sound with Application to the Air Propeller, S. Albert Reed. Aerial Age, vol. 16, no. 4, Apr. 1923, pp. 182–185, 6 figs. Results of tests with Reed one-piece solid metal semi-flexible propeller.

AIRPLANES

Fokker. Fokker F5 Commercial Transport Airplane. Aviation, vol. 14, no. 14, Apr. 2, 1923, pp. 367–369, 4 figs. Convertible wing feature permits of speed and load variation for different services.

Wright All-Metal Pursuit. The Wright All-Metal Pursuit Airplane. Aviation, vol. 14, no. 14, Apr. 2, 1923, pp. 364–366, 2 figs. Duralumin cantilever monoplane characterized by excellent performance and military adaptability. Built by Dornier Co. in Switzerland, to fill American requirements.

AIRSHIPS

Goodyear Army TCl. Trials of New Goodyear Army Airship TCl. Aviation, vol. 14, no. 14, Apr. 2, 1923, p. 371, 1 fig. Novel features of non-rigid airship of 200,600 cu. ft. gas capacity; fitted with two 150-hp. Hispano-Suiza engines.

U. S. ZR3. Characteristics of U. S. Naval Airship ZR3. Aviation, vol. 14, no. 14, Apr. 2, 1923, p. 366, 1 fig. Capacity, 68,000 cu. m.; overall length, 206 m.; diam., 27.9 m.; max. breadth, 28 m.; max. height, 31 m.; power plant, five 400-hp.; max. speed, 79.3 mi. per hr.; cabin accommodations with sleeping quarters, 30 passengers.

AUTOMOBILE FUELS

Volatility. Motor-Transport Performance with Varied Fuel-Volatility, C. T. Coleman. Soc. Automotive Engrs.—Jl., vol. 12, no. 4, Apr. 1923, pp. 343–350, 9 figs. Data obtained regarding economic operation of motor vehicles with fuels of varied volatility, under service conditions.

AUTOMOBILES

Steering Systems. A Critical Study of Modern Automotive-Vehicle Steering-Systems, Herbert Chase Soc. Automotive Engrs.—Jl., vol. 12, no. 4, Apr. 1923, pp. 377–388 and (discussion) 388–397, 33 figs. Discussion of steering-gear faults.

BOILER PLANTS

Reconstruction. Rebuilding Boiler Plant Reduces Coal Consumption over One-Half. Power, vol. 57, no. 15, Apr. 10, 1923, pp. 546–552, 11 figs. Modern plant containing 6 water-tube boilers varying in size from 4000 to 5000 sq. ft. of heating surface, was built on site of old overload plant containing 15 boilers, without interruption to service.

BOILERS

A.S.M.E. Code. Comments on A.S.M.E. Revised Code for Testing Stationary Boilers, David Brownlie. Power, vol. 57, no. 15, Apr. 10, 1923. pp. 575–577, 1 fig. Criticism and suggestions for further revision, and necessity of international code.

CARBURETORS

Cadillac. Cadillac Makes Detail Changes in Carbureter Design. Automotive Industries, vol. 48, no. 13, Mar. 29, 1923, pp. 724–725, 1 fig. Double thermostat now used to govern relief of pressure on carbureter bowl; float valve redesigned.

CASE HARDENING

Method. New Method of Case Hardening, Frank Hodson. Forging & Heat Treating, vol. 9, no. 3, Mar. 1923, p. 160. Process introduced and patented by Assar Gronwall of Sweden consists of converting carbonic acid as formed to carbon monoxide.

CENTRAL STATIONS

Economic Operation. Effects 35 Per Cent Reduction in Generating Cost, D. E. Druen. Power, vol. 57, no. 13, Mar. 27, 1923, pp. 470–474, 5 figs. Changes in operating practices and building up of efficient personnel have resulted in average saving of $1000 per day in 50,000-kw. station of Kansas City Railways.

COST ACCOUNTING

Shop Office. Shop Office Accounting, Norman G. Meade. Indus. Management (N. Y.), vol. 65, no. 4, Apr. 1923, pp. 216–220, 14 figs. How three large corporations keep track of materials and stock.

COSTS

Graphic Analysis. Solving Cost and Economy Problems by Graphs, James A. Brown. Management Eng., vol. 4, no. 4, Apr. 1923, pp. 251–254, 3 figs. Management questions mathematically analyzed.

CUPOLAS

Charging System. Devise Flexible Charging System. Foundry, vol. 51, no. 7, Apr. 1, 1923, pp. 276–279, 7 figs. Describes layout adopted by Muncie Foundry & Machine Co., Ind., for handling materials from railway car to yard and from yard to cupola.

DIE CASTING

Methods. Die-Sinking Under a Drop-Hammer, Fred H. Colvin. Am. Mach., vol. 58, no. 12, Mar. 22, 1923, pp. 449–450, 4 figs. Method which saves time and money and helps to reduce cost of die castings; adaptation of silverware methods to another field.

ECONOMIZERS

Foster. New Foster Economizer. Power, vol. 57, no. 13, Mar. 27, 1923, pp. 485–486, 2 figs. Differs widely from those in general use, namely, in size of tubes used, placing them in horizontal position, use of cast-iron gilled rings on outside of steel tubes, and employment of water for cleaning tubes in place of scraper or steam blowers.

ELECTRIC WELDING, ARC

Cyc-Arc. A Development of the Cyc-Arc Welding Process. Engineer, vol. 135, no. 3508, Mar. 23, 1923, pp. 306–309, 9 figs. With present machine it is said to be possible not only to weld dissimilar metals and alloys together, but also identical metals.

Flash. Flash Welding, A. L. De Leeuw. Am. Mach., vol. 58, no. 12, Mar. 22, 1923, pp. 433–436, 5 figs. Advantages over slow butt welding; current consumption and pressures required; limitations; welding non-ferrous metals.

EMPLOYEES

Rating Scales. Are Rating Scales Justified? Eugene J. Benge. Indus. Management (N. Y.), vol. 65, no. 4, Apr. 1923, pp. 199–202, 4 figs. Results of investigation conducted by author on group of 51 men in attempt to analyze criticisms of rating-scale validity.

FORGE SHOPS

Germany. Famous German Forging and Machine Plant, Godfrey L. Garden. Iron Age, vol. 111, no. 13, Mar 29, 1923, pp. 886–887, 3 figs. Describes plant of Haniel & Lueg at Düsseldorf for manufacture of steam-hydraulic presses, blowing and gas engines, pumps and rolling mills.

FORGING

Hydraulic Presses. Observations on the Construction and Installation of Hydraulic Forging Presses, W. R. Ward. Forging & Heat Treating, vol. 9, no. 3, Mar. 1923, pp. 143–146. Outline of manufacture of forging presses; various operations and materials; foundations; installation and testing.

FOUNDRIES

Labor-Saving Machinery. Eliminating Skilled Foundry Labor, F. L. Prentiss. Iron Age, vol. 111, no. 14, Apr. 5, 1923, pp. 949–954, 10 figs. Special machines and conveyors result in producing 500 Chevrolet 4-cylinder castings per day with only 17 semi-skilled men and 28 flasks.

GAGES

Measuring Machine. The Wickman Gauge Measuring Machine. Engineer, vol. 135, no. 3506, Mar. 9, 1923, pp. 266–268, 8 figs. Machine for verification of workshop gages, to be carried out quickly and accurately.

GEARS

Burnishing. Burnishing the Teeth of Gears, Ellsworth Sheldon. Am. Mach., vol. 58, no. 9, Mar. 1, 1923, pp. 325–326, 1 fig. Corrects minor errors of contour, smooths and densifies tooth surface; analogous to cold hammering; forestalls effects of distortion in hardening

INDUSTRIAL MANAGEMENT

Methods and Principles. Management Methods and Principles of Frank B. Gilbreth, Inc., K. H. Condit. Am. Mach., vol. 58, nos. 1, 8 and 12, Jan. 4, Feb. 22 and Mar. 22, 1923, pp. 33–35, 293–295 and 443–447, 14 figs. Jan. 4: Principles of application of psychology to management. Feb. 22: Plant survey; use of stereoscopic camera; collecting blank forms, written orders and blueprints; disposition of useless material; process charts. Mar. 22: Principles upon which process chart is constructed and tools used; functions of organization chart; route models and their use.

Statistics of Industry. Signals for Business Conditions, Ernest F. DuBrul. Management Eng., vol. 4, no. 4, Apr. 1923, pp. 259–264, 5 figs. Statistical flags of industry show what to do and when to do it. Points out that study of industry's statistics of orders and prices enables one to lay out proper division of its cycle into various sectors.

LOCOMOTIVES

Exhaust-Steam Utilization. Condensing and Utilisation of Exhaust Steam in Locomotives. Engineer, vol. 135, nos. 3507 and 3508, Mar. 16 and 23, 1923, pp. 279–281 and 303–304, 7 figs. Consideration under two heads: (1) locomotives which condense comparatively small volume of exhaust, generally for purpose of feedwater heating; (2) locomotives which condense whole of exhaust in order to expand steam down to lowest pratical possible pressure below that of atmosphere.

MOLDING METHODS

Green-Sand Cores. Foundryman Develops New Practice, H. E. Diller. Foundry, vol. 51, no. 7, 1923, pp. 252–256, 9 figs. Describes method developed by Edwin Jory of handling green-sand cores in mold. Molding operations and devices in gray iron and steel shop.

OFFICE MANAGEMENT

Routine Charts. The Use of Routine Charts, G. Charter Harrison. Management Eng., vol. 4, no. 4, Apr. 1923, pp. 223–228, 2 figs. Improving and systematizing office procedure. Author shows by example how to analyze procedure by arranging various forms on chart.

RAILWAY SHOPS

Production Methods. Production Methods in a Railroad Shop, L. S. Love. Iron Age, vol. 111, no. 13, Mar. 29, 1923, pp. 881–885, 25 figs. Improvements in fixtures and tools effect savings in cost of work; parts machined in multiple fixtures; waste material reduced.

Scrap Reclamation. Railroad Salvage and Other Shop Work, S. Ashton Hand. Am. Mach., vol. 58, no. 13, Mar. 29, 1923, pp. 469–472, 14 figs. Reclamation of materials; substitute for turntable; milling teeth in spherical cutter. Practice at Emerson Shops of Atlantic Coast Line R. R., South Rocky Mount, N. C.

STEAM-ELECTRIC PLANTS

Oil-Burning. High Efficiency Oil-Burning Station, C. H. Delany. Elec. World, vol. 81, no. 13, Mar. 31, 1923, pp. 735–738, 7 figs. Installation of 12,500-kw. horizontal turbine, operating at 1800 r.p.m. directly connected to 3-phase, 60-cycle, 12,000-volt generator; boilers are provided with steam-atomizing oil burners; use of graphic meters.

STEEL MANUFACTURE

Electric-Furnace. Electrically Melted Ferro-Manganese Improves Converter and Open Hearth Practice, Frank Hodson. Blast Furnace & Steel Plant, vol. 11, no. 4, Apr. 1923, p. 243, 1 fig. Points out with proper metallurgical manipulation of ferro-manganese, it is desirable to use electric furnace with large open bath rather than restricted channel.

Figuring Alloys. Short Method for Figuring Alloys, J. M. Quinn. Blast Furnace & Steel Plant, vol. 11, no. 4, Apr. 1923, pp. 232–238. Comprehensive system of tables and proportions used by practical steel makers.

STOKERS

Low-Grade Fuel. Stokes Anthracite Culm and Gas-house Tar, Joseph Harrington. Power, vol. 57, no. 14, Apr. 3, 1923, pp. 523–524, 3 figs. Mixture of anthracite dust and liquid tar from gas producers is burned successfully on forced-draft chain-grate stokers with no modification of furnaces at plant of Consolidated Gas & Elec. Co., Long Branch, N. J.

Pluto. The Pluto Mechanical Stoker. Engineering, vol. 115, no. 2985, Mar. 16, 1923, pp. 325–328, 25 figs. Arrangement and details of stokers developed by N. V. Maatschappig Pluto, of Nijmegen, Holland, which are in successful use in large power station at Amsterdam and elsewhere on Continent.

WAGES

Merit System. A Merit System for Establishing Wage Rates, K. H. Crumbine. Am. Mach., vol. 58, no. 8, Feb. 22, 1923, pp. 301–302. Describes universal plan based only on merit, claimed to be just to all employees.

WATER POWER

New York. Availability and Economics of Hydro-Electric Power for New York. Power, vol. 57, no. 14, Apr. 3, 1923, pp. 508–514. Abstracts of following papers: Coördinated Statement of Problem, F. W. Scheidenhelm; Available Water Power and Cost of Delivery, W. S. Murray; Requirements of Service for Hydro-Electric Power, George A. Orrok; Factors Affecting Quality of Hydro-Electric Service, F. A. Allner; Reliability of Long-Distance Transmission, Lorin E. Imlay. Discussion.

New York State's Water Power, Guy E. Tripp. Elec. World, vol. 81, no. 12, Mar. 24, 1923, pp. 685–686, 1 fig. Reasons why it must not be isolated or developed individually; advantages of interstate transmission and superpower systems which embrace steam-driven as well as water-power stations.

WOODWORKING MACHINES

Planing and Molding. High-Speed Wood Planing and Moulding Machines. Engineering, vol. 115, no. 2986, Mar. 23, 1923, pp. 365–366, 6 figs. partly on supp. plate. One machine is capable of producing tongued-and-grooved flooring and matchboarding at speed of 250 ft. per min., and other of shaping boards to various moldings at 80 ft. per min.

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Mechanical Engineering

The Monthly Journal Published by

The American Society of Mechanical Engineers

Publication Office, 207 Church Street, Easton, Pa. Editorial and Advertising Departments at the Headquarters of the Society, 29 West Thirty-ninth Street, New York

Volume 45 June, 1923 Number 6

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ADVERTISING

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Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879.
Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921.

Contributors and Contributions

U. S. Navy Crane Ship No. 1

The vital part that high-grade engineering plays in the defense of the country is reëmphasized by the article in this issue describing the largest floating crane in the world—and the only sea-going one—into which the old battleship *Kearsarge* has recently been converted. The difficult nature of the engineering problems involved in rebuilding the hull and in constructing the crane will be readily apparent, and their solution reflects great credit upon American engineers, in particular those of the U. S. Navy and of the Wellman-Seaver-Morgan Company who were charged with the responsibility for the achievement.

Orifice Coefficients

Jacob M. Spitzglass, vice-president and consulting engineer of the Republic Flow Meters Company, Chicago, Ill., presents a paper discussing the results of extended experimental work conducted at the research laboratory of his company on the use of orifice plates for measuring the flow of fluids in pipes.

Mr. Spitzglass was born in Russia in 1869. After unsuccessful attempts to obtain a technical education there and in Western Europe he came to America and in 1909 was graduated from the Armour Institute of Technology with the degree of B.S. in mechanical engineering. Four years later he received his M. E.

His first position after graduation was with the Northwestern Gas Light and Coke Company. Then for a year he tested steam engines for the Armour Glue Works and experimented in measuring the flow of steam to the various lines of the concern. He later was engaged to do experimental work for the People's Gas Light and Coke Company and won recognition for his work relating to the flow of fluids through pipes. He improved and developed the Gebhardt steam meter. This meter is now being manufactured by the Republic Flow Meters Company. Mr. Spitzglass has received the Longstreth Medal for his work in developing and correcting the defects of the steam meter.

Recent Developments in Balancing Machines

With the increased speed and capacity of motors the necessity for satisfactory balancing equipment has been keenly felt, especially for the balancing of small high-speed motors for domestic use. A machine which makes it possible to manufacture quietly running motors is described by Carl R. Söderberg in this issue.

Mr. Söderberg is a native of Sweden, where he was born in February, 1895. He was graduated from the Technical Preparatory School at Härnösand in 1914, served two years as an apprentice in the shipbuilding industry, and then entered Chalmer's Institute of Technology, Gothenburg, from which he was graduated in 1919. With a scholarship from the American-Scandinavian Foundation for study of the shipbuilding industry in America, he came to this country and pursued post-graduate work at the Massachusetts Institute of Technology and the University of Michigan until June, 1920. Since then he has been employed successively by the New York Shipbuilding Corporation at Camden, and the Westinghouse Electric and Manufacturing Company at East Pittsburgh, where he has specialized on vibration problems.

Steel-Car Construction

The first box car having its entire frame built of steel was originated by the Canadian Pacific Railway nearly fifteen years ago. In this issue H. R. Naylor, assistant works manager of the Angus Shops of the Canadian Pacific, at Montreal, Canada, describes the shop specially erected to fabricate the steelwork for these cars, giving particulars regarding its layout, crane facilities, machine equipment, etc. He presents the various machining operations and the jig method of car assembly now employed and the method used in the final erection and finishing of the cars.

Mr. Naylor was born in England in 1885 and served his apprenticeship in railway engineering in that country. He entered the service of the Canadian Pacific Railway Company in 1907 as patternmaker and has served that company in various capacities since that time, assuming his present position about three years ago.

Industrial Safety Codes

The brief paper on the development of industrial safety codes appearing in this issue was presented by M. G. Lloyd, chief of the Safety Section of the U. S. Bureau of Standards, and vice-president of the American Society of Safety Engineers, at a joint session of that society and the A.S.M.E. Safety Codes Committee at the A.S.M.E. Annual Meeting in December, 1922.

Mr. Lloyd is a graduate of the University of Pennsylvania, which has conferred upon him the degrees of Bachelor of Science, Doctor of Philosophy, and Electrical Engineer. After serving as instructor of physics at this university he became connected with the Bureau of Standards and was engaged for several years in electric and magnetic testing and research. From 1910 to 1917 he was technical editor of the *Electrical Review and Western Electrician*. He returned to the Bureau in 1917.

Code for Care of Power Boilers

The Proposed Code for the Care of Power Boilers, formulated by a Sub-Committee of the Boiler Code Committee and containing rules for the care of steam boilers and other pressure vessels in service, is now presented for public discussion. A hearing on this report is on the program of the A.S.M.E. Spring Meeting at Montreal. When revisions are completed this report will form a part of the A.S.M.E. Code.

A.S.M.E. Spring Meeting

The Montreal Meeting of The American Society of Mechanical Engineers is in progress as this issue of MECHANICAL ENGINEERING is being mailed. An account of the technical sessions will appear in the July issue.

The A.S.M.E. News for June 7 will tell of the excursions and of the social events.

MECHANICAL ENGINEERING

Volume 45 | June, 1923 | No. 6

U. S. Navy Crane Ship No. 1: An Achievement

Details of the Conversion of the Battleship "Kearsarge" into a Titanic Seagoing Crane for Handling Loads of 250 Tons—The Engineering Problems Encountered in Dealing with Stresses of Unprecedented Magnitude and How They Were Solved

When in an engineering structure the size exceeds certain well-tested limits, the difficulties of design and construction multiply at a very rapid rate. There have been many instances of this character. Steel bridges have been built for many years, but when it came to an enormous structure like the Quebec Bridge it was found that our knowledge of stresses of the magnitude involved was insufficient. The same type of difficulty was encountered and overcome in converting the battleship *Kearsarge* into a seagoing crane ship capable of handling and transporting two modern three-gun turrets complete with their guns.

"U. S. Navy Crane Ship No. 1" as it is known officially but called the "*Kearsarge* Crane," is the only large seagoing crane ever constructed and the largest floating crane in existence. Big floating cranes have been built in the past, but only for harbor work and not for navigation in rough water or in heavy seas. The *Kearsarge* bears a 250-ton revolving crane of the luffing-jib type so designed that the jib may be lowered into a cradle and secured firmly for sea service. Built to handle loads of 250 tons under normal conditions, she has actually lifted 312 tons. Such loads on a floating structure impose stresses of an unprecedented character, both on the crane and the foundation, which means that all parts have to be designed with unusual care, generous factors of safety, and with particular regard to the selection of materials in order that there shall be no weakening of any part due to overstressing. To meet these conditions interesting expedients and methods of design were resorted to, both by the Navy Department, in whose hands was the reconditioning of the hull, and by the Wellman-Seaver-Morgan Co., of Cleveland, Ohio, the builders of the crane itself. Among these may be mentioned a new method of combined welding and riveting ship plates, the novel track arrangement for the crane, the rotating mechanism—provided with wheels of a new type, the methods of cradling the crane at sea, etc.

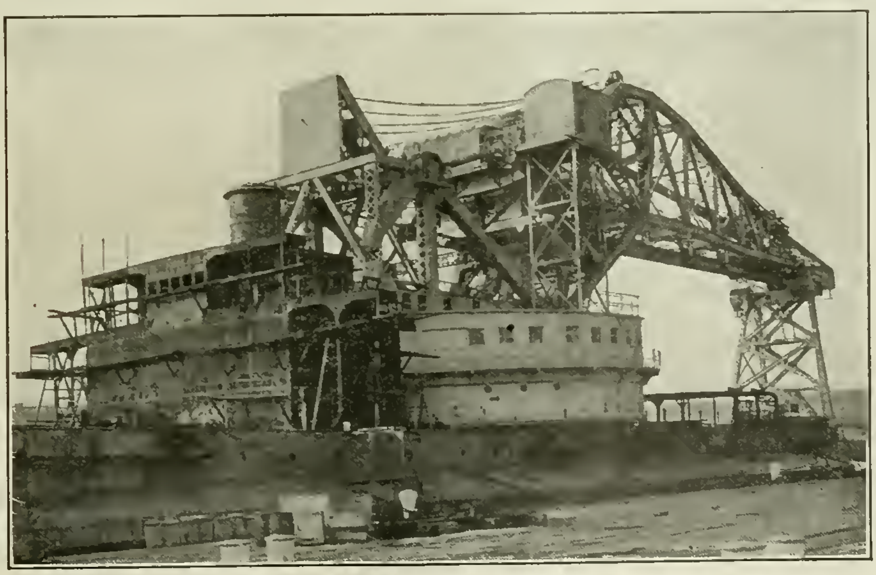

Fig. 1 When Ready for Sea, the Jib Rests in a Cradle at the Stern of the Crane Ship

Special Usefulness of the Large Seagoing Crane

Cranes of this type are expected to prove useful in many ways. For fitting-out purposes, handling guns, turrets, boilers, etc., they are beyond comparison with any other type as they can be easily moved to any point where their service is required. This is a very decided advantage as it permits the use of a crane not only at different places in the same base but also extends the scope of operations to yards which would otherwise be unable to command such facilities. The utility of a seagoing crane, however, is not limited to work around navy yards and piers. Its value in salvage operations cannot be overestimated. With the extreme facility of movement possessed by the *Kearsarge* crane, it is quite possible that a sunken submarine might be salvaged if the work were undertaken before the conditions became too unfavorable. In fact, a sunken tug was salvaged during the war by a 150-ton pontoon crane.

The name "Kearsarge"—that of a mountain in Merrimac County, New Hampshire—is one with a long and honorable record in the annals of the United States Navy. The first vessel to bear it was a gunboat hastily built in the early days of the Civil War. Immediately upon completion it was dispatched to European waters to protect United States shipping from the depredations of Confederate privateers. It achieved fame by sinking the *Alabama*, one of the South's speediest and most successful ships. A quaint insight into the knightly attitude of the two American navies is given in the report of Capt. John A. Winslow, of the *Kearsarge*, dated June 19, 1864, from Cherbourg, France, to Secretary of the Navy Gideon Welles in reference to the battle with the *Alabama*. "I have the honor to inform the Department," wrote Captain Winslow, "that the day subsequent to the arrival of the *Kearsarge* off this port I received a note from Captain Semmes [of the *Alabama*] begging that the *Kearsarge* would not depart, as he intended to fight her and would delay her but a day or two." There was no such exchange of notes with the enemy in the recent war. The old *Kearsarge* was wrecked on February 2, 1894, on Roncador Reef in Central American waters, and the construction of a new one was authorized by act of Congress of March 2, 1895. This vessel was built at the Newport News Shipbuilding and Drydock Co. yards, Newport News, Va., and was launched on March 24, 1898.

Old or new, the *Kearsarge* embodied novel features. The original vessel, together with her sister ship the *Kentucky*, was selected for an experiment in the installation of superposed turrets, an 8-in. turret being rigged on top of a 13-in. The later *Kearsarge* and the *Kentucky* (now to be scrapped as a result of the Washington Conference) were the first to be completely equipped with electric auxiliaries such as turret-operating machinery, deck winches, ventilating fans, etc.

Beginning the Work of Conversion

After the World War the need of a mobile crane for the use of

the Navy became apparent, and the conversion of the *Kearsarge* into a crane ship was decided upon largely because the hull of the vessel was in an excellent state of preservation and suitable for the purpose in view.

At the beginning of the conversion the guns, turrets, much of the armor, the upper works of the vessel, and a number of the boilers were removed. Little was done to the hull, but it was found necessary to widen the beam by the construction of large bulges on the outside of the hull for the purpose of increasing its transverse stability. These bulges are divided into a number of watertight compartments.

Plate from "Romance of the American Navy," Courtesy G. P. Putnam's Sons

Fig. 2 The First U. S. S. *Kearsarge* Became Famous Through Sinking the *Alabama* Off the Coast of France in 1864

Reinforcing the Hull

In order to carry the immense load and stresses imposed by the presence of the crane and possible loads of the upper decks, the whole ship structure had to be materially reinforced. Just to show the magnitude of these loads, it may be stated that a preliminary calculation showed that the presence of the crane would impose a tangential load of the order of 460,000 lb. acting with a lever arm of 42 ft. 8 in. from the top of the roller path of the crane. So great were these loads that for a while it appeared to be doubtful whether the hull of the ship would be strong enough to withstand their terrible tearing action. The entire structure was accordingly reinforced by an ingenious and liberal use of columns, gusset plates, etc.

In this work some interesting expedients were adopted. Thus, the entire main deck consisting of triple plates was, in addition to the usual riveting, electrically butt-welded in such a manner that the top plate is now practically a single piece from end to end.

In the matter of carrying the main deck loads by the vertical partitions, it was found difficult to select a design of angle which would have sufficient metal left after the necessary rivets had been driven in. It was one of the cases familiar in bridge construction of either enough rivets and not enough metal left in the plate, or enough plate and not enough rivets. The problem was solved after preliminary tests in the ingenious way shown in Fig. 3. Here the vertical wall does not quite reach to the horizontal plate, and the angle in addition to being riveted is welded to the vertical plate all along its lower edge. The result is that much of the shear stress is taken off the rivets and transferred to the welded edge, which under these conditions is capable of carrying safely quite a considerable load.

This is but one instance of the care in design exercised by the engineers of the Navy Department in the reconstruction of the hull. Another is that all doors in the inner walls of the hull are made oval shaped and reinforced by heavy plate frames.

The duty of the Navy Department in reconstructing the hull for the reception of the crane ended with the preparation of the main deck carrying frame for the crane. This latter represented substantially a ring roughly 60 ft. in diameter the upper surface of which had to be level within very close tolerances. This was made possible by increasing the rigidity of the hull structure by the means referred to above. A rather interesting water level which was rigged up permitted the testing of any number of points on the circular track simultaneously.

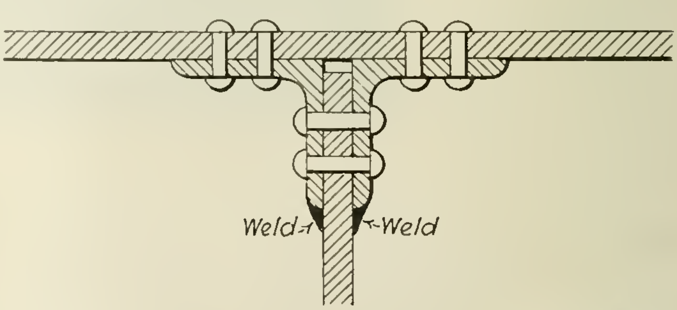

Fig. 3 Method Used in Attaching Vertical Wall to Deck Plate

Nature of the Engineering Problems Involved

The engineering problems encountered by the Navy were, however, only a small part of those involved in the construction of the crane proper, this latter having been carried out under contract by the Wellman-Seaver-Morgan Company, of Cleveland, Ohio. Stationary cranes had been built in sizes much larger than the *Kearsarge* unit and floating cranes of a type much smaller, but never before had it been attempted to complete a floating crane of this size. Such construction involved difficulties of a nature never before encountered. In the first place, the designer had to deal with stresses of an unprecedented magnitude and little-known character.

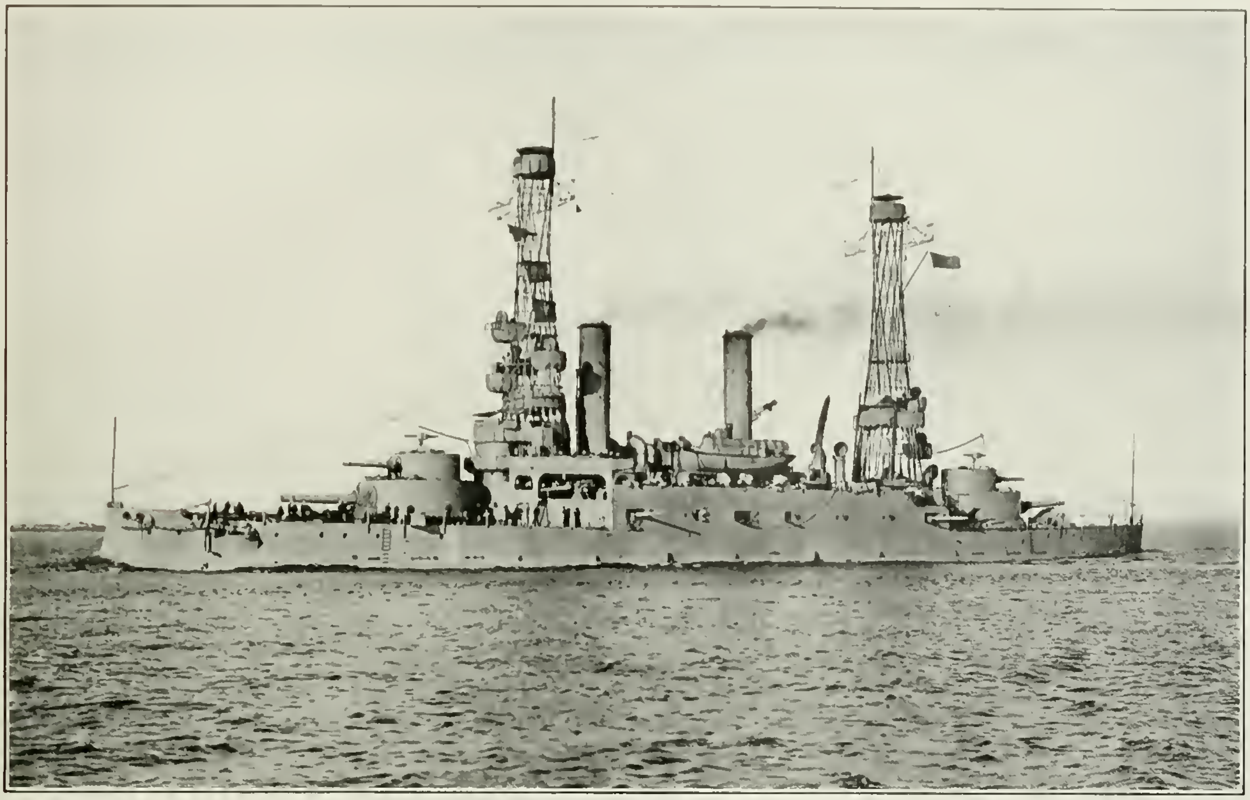

Fig. 4

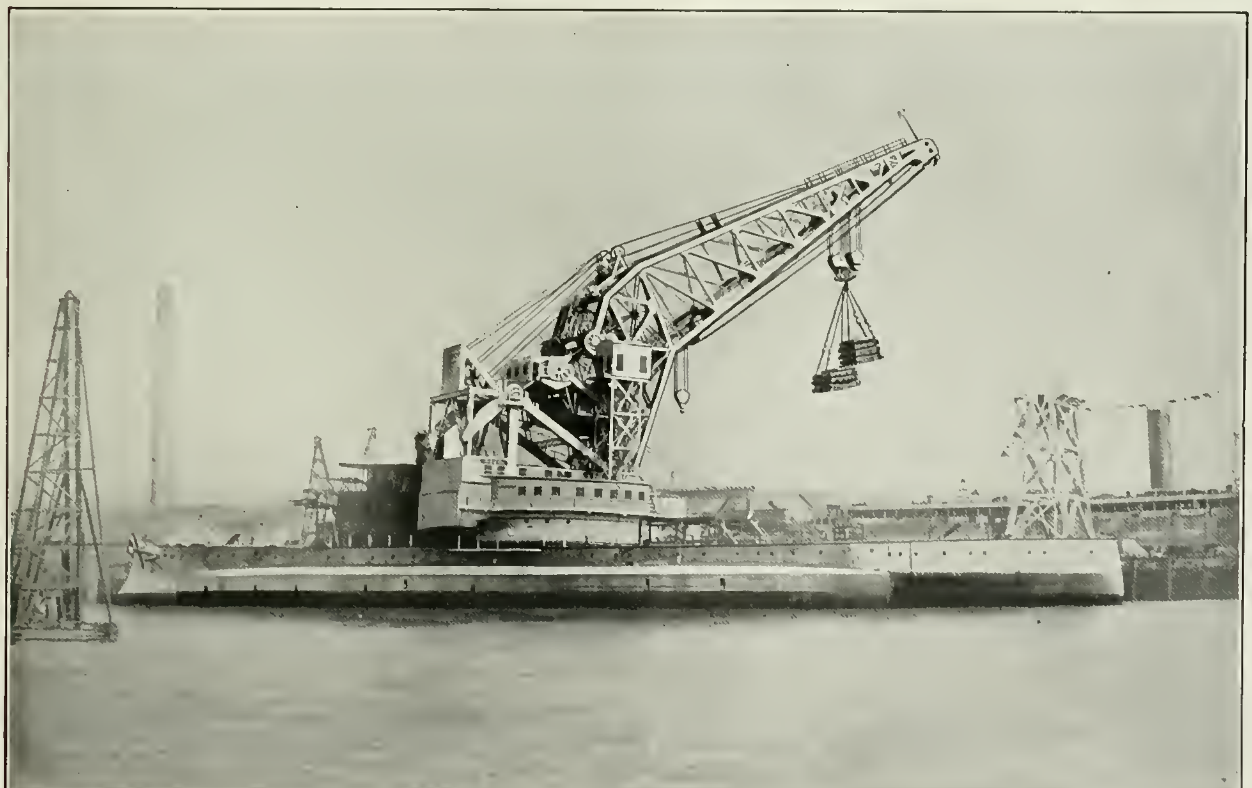

Fig. 5

In Its Naval Career the "Kearsarge" Has Played Two Rôles

Fig. 4 shows the *Kearsarge* as a battleship in active service. Fig. 5: Rebuilt into U. S. Navy Crane Ship No. 1 mounting a 250-ton revolving crane the *Kearsarge* is handling a full load under test. Note the cradle at the stern of the ship in which the jib is held while at sea, and the bulge to increase the ship's beam. The auxiliary hoist appears at the lower end of its trolley on the jib.

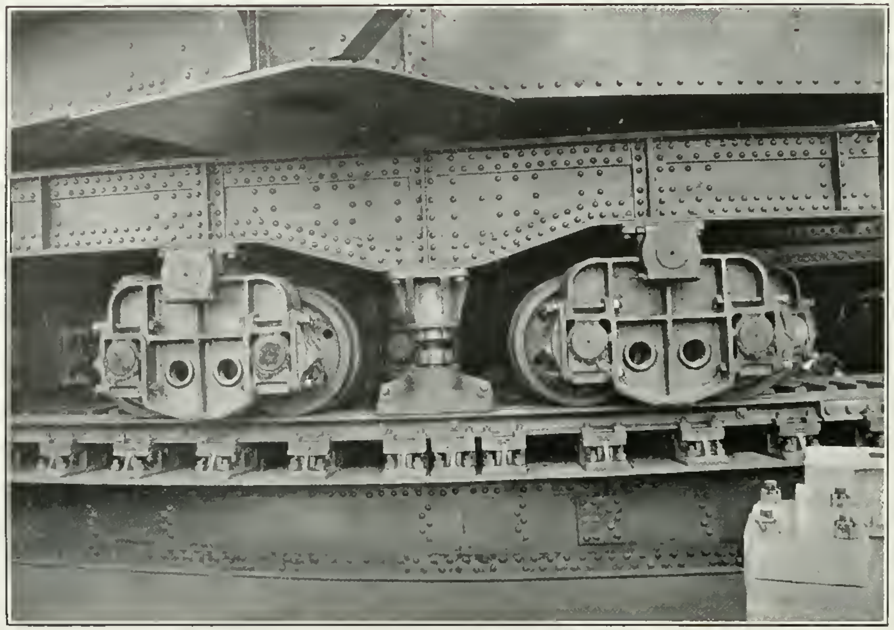

Fig. 6

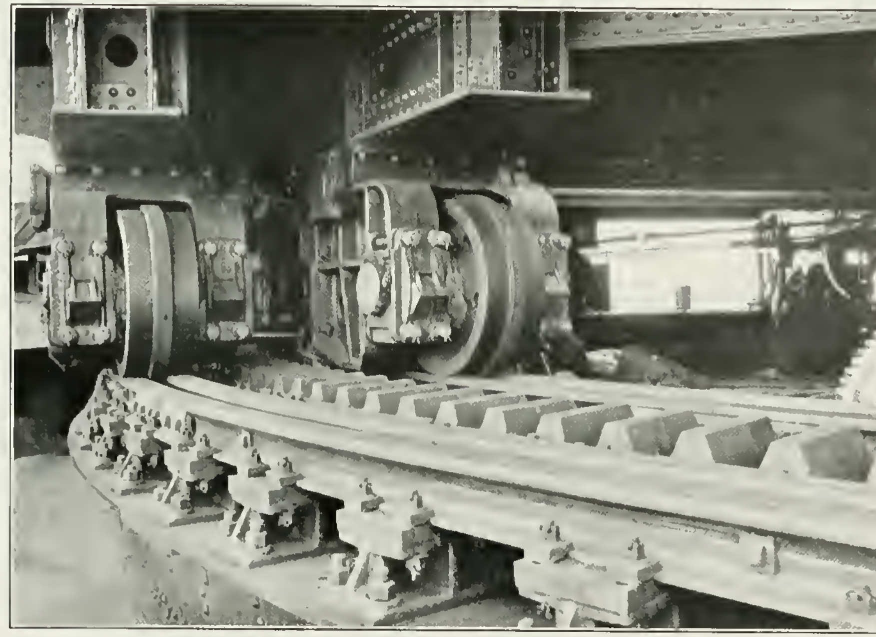

Fig. 7

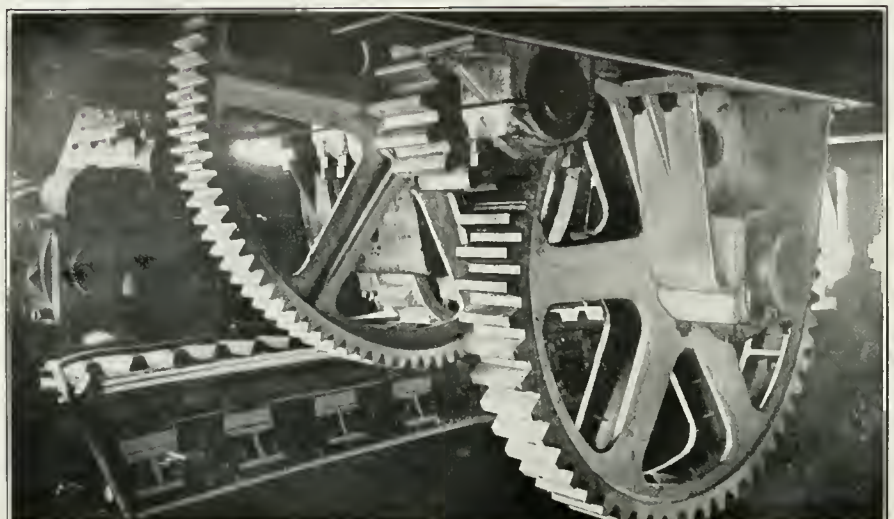

Fig. 8

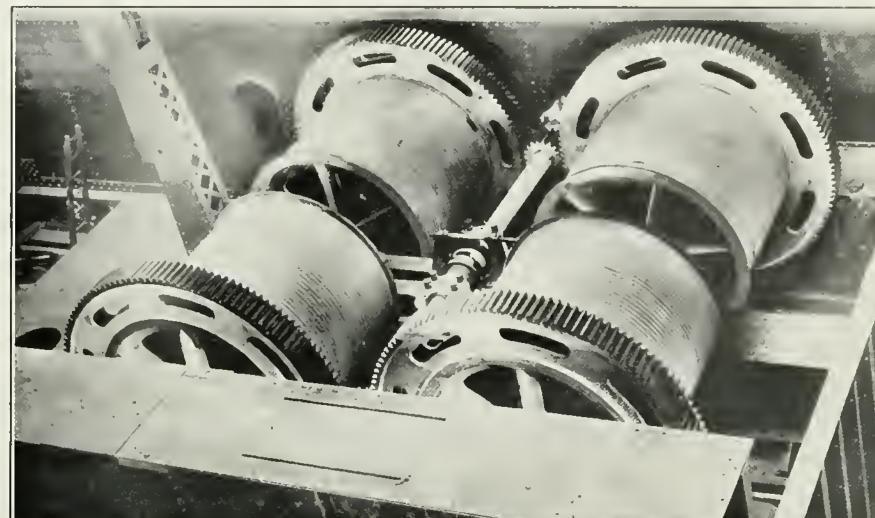

Fig. 9

Details of Design Are Rugged

Figs. 6 and 7 show the interesting method of supporting the crane superstructure. Fig. 6 makes especially clear the equalizing action of the supports which enables the crane superstructure to conform to any deflection in the track. The important lifting jack for use when jib is cradled is also shown between the two trucks. In Fig. 7 the conical rollers are displayed as is the rack through which the rotating mechanism operates. The gear train and part of the rotating mechanism are shown in Fig. 8 while in Fig. 9 the large hoisting drums may be seen.

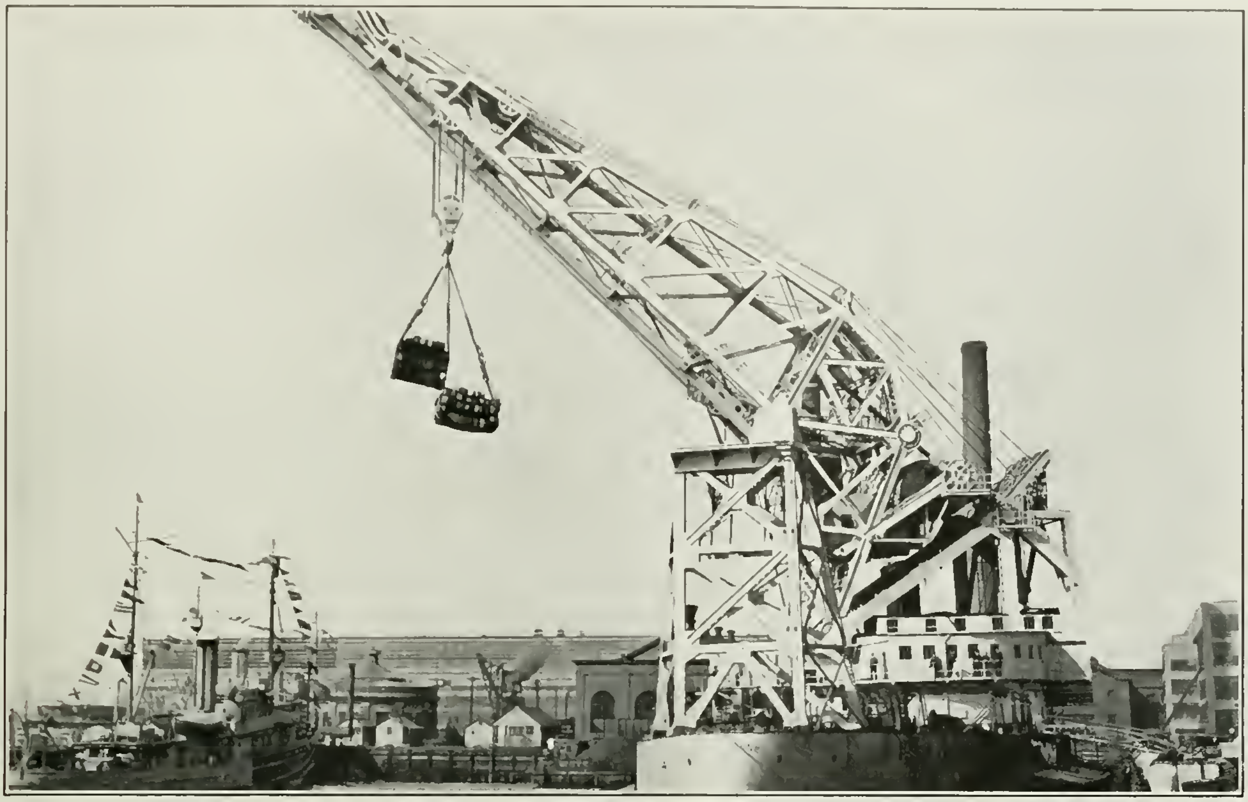

Fig. 10

Fig. 11

The Crane Ship Operates Under Widely Varying Conditions

The crane ship can handle 250 tons at 101 ft. radius from the center of rotation. Fig. 10 shows this with the ship on even keel. Using the auxiliary hoist the crane can handle 50 tons at 173 ft. radius with the hoist at the extreme end of the trolley. Fig. 11 shows this and also the two main hoists of 125 tons each, which can be used together to handle 250 tons. Fig. 10 shows the jib nearly at its highest position, while in Fig. 11 the jib is nearly horizontal.

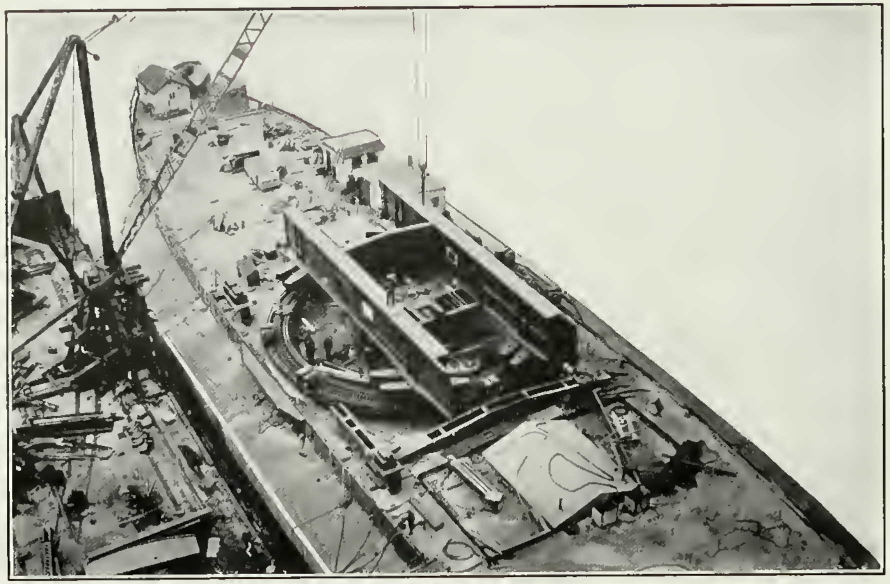

Fig. 12

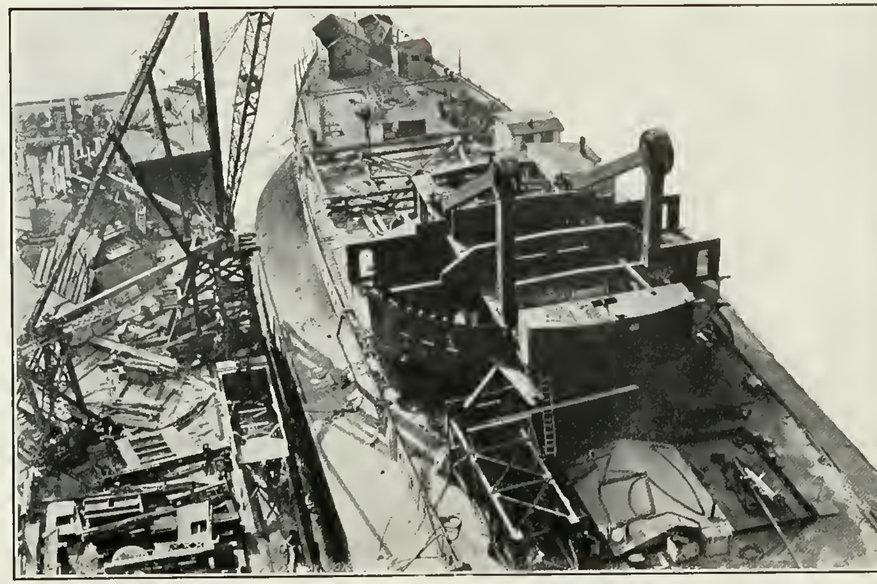

Fig. 13

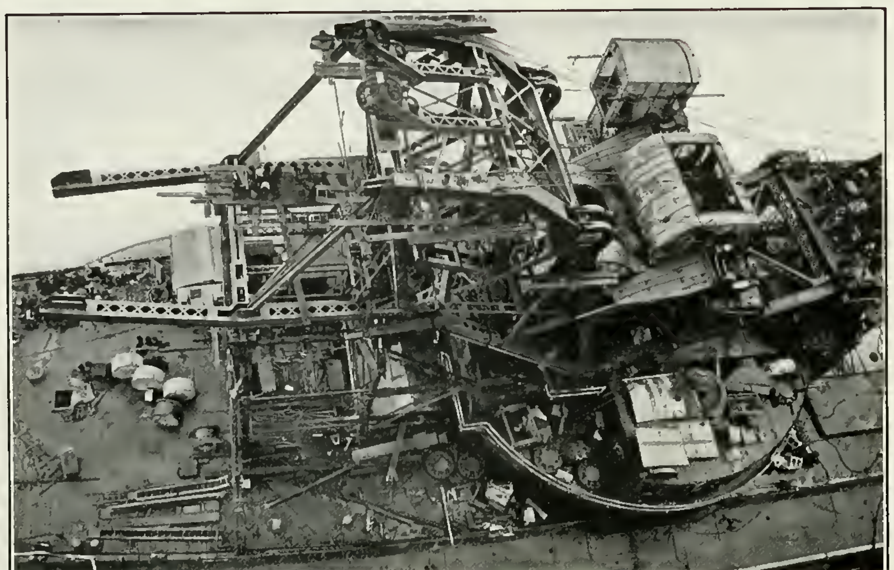

Fig. 14

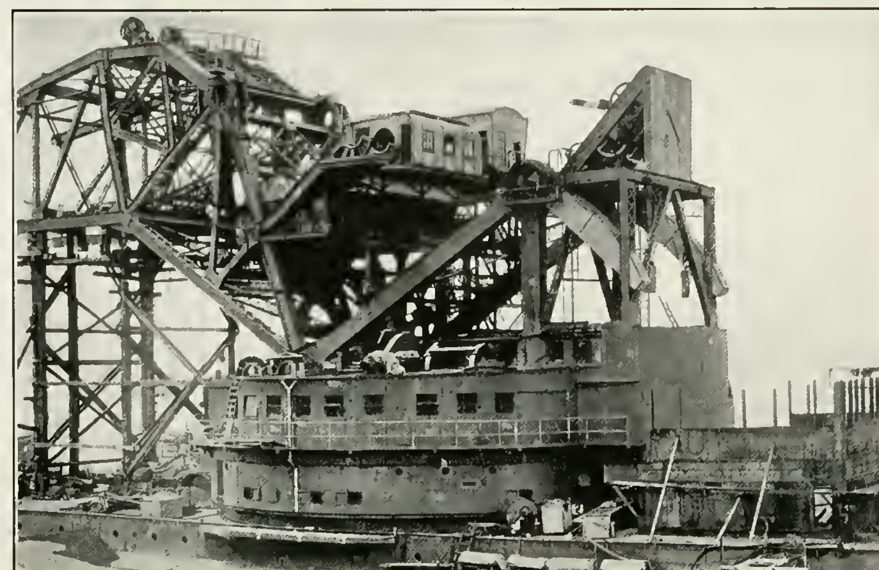

Fig. 15

Erection Pictures Show Fundamentals of Design

Fig. 12 (January 3, 1922) The foundation frame of the superstructure is built of two girders, each resting on four equalizing girders, a pair under each end. Details of the latter are shown in Figs. 6 and 7. Fig. 12 also shows two trucks placed on the outer circular track on each side of the main frame. These four trucks are for support of the outrigger girders shown at right angles to the foundation girders in Fig. 13 (January 23, 1922). Note the widening effect of the hull bulges in these two figures. Figs 14 (March 31) and 15 (May 31) show the construction of the jib well under way. The hoisting machinery is being used to bring the jib members into position.

The Navy specifications demanded that the crane should be capable of withstanding the roll of a ship of the order of 25 deg. complete in 3 sec., which imposed on every part of the structure an enormous strain. Furthermore, this was to be a seagoing unit, which meant that it might have to encounter rough weather. Every part, therefore, had to be cradled in such a manner that when the vessel was traveling in the open sea there would be no pounding—not an easy proposition with a structure in excess of 40 ft. high above the deck level and weighing millions of pounds. Finally, the crane had to operate on a circular track of 60 ft. mean diameter in a floating structure, that is, one inevitably subject to distortions, and yet remain under perfect control. The whole structure was so large that the manufacture of parts which otherwise would have been merely a matter of routine became a serious engineering problem in itself.

To give but one instance, luffing screws had to be made in sizes 15 in. in diameter and 28 ft. long, while the nuts for them were 5 ft. long, 26 in. in diameter, and about 5000 lb. each in weight. It was a man-sized job to handle parts of this character, and it is a high testimonial to American engineering that every detail of the crane was designed and manufactured in the United States—not because there were any restrictions imposed as to the procurement of parts abroad, but because facilities were available here to do everything to the complete satisfaction of the parties involved, and with excellent success as the tests have shown.

Design and Construction of the Crane

The *Kearsarge* crane is of the luffing-jib type and is so designed that the jib may be lowered to rest in a cradle at the stern of the ship. (Fig. 1.) In view of the great weight of the crane and the fact that it was to be installed on a seagoing vessel, it was very important to arrange it so that it would be in a perfectly steady position while the ship was under way. To provide for this the crane when not in use is supported at three points. In the first place, it is securely held in the cradle just referred to, which is a substantially built tower. Next, it is held by the center pin about which it rotates; and finally in the rear, back of the rotating track and under the counterweight, there is a heavy pin held in a rigidly constructed frame. The whole structure is such that the jib cannot move notwithstanding the rolling of the ship. The crane is provided with four hooks, two of 125 tons lifting capacity each, one 250-ton compensator-type hook, and a light 40-ton hook on a special trolley for emergency work. Special cradles are provided for these hooks so that when the ship is under way there are no swinging parts.

The operating equipment of the crane consists of two main hoists of 125 gross tons capacity each, operated by separate motors and so arranged that they may be coupled together when handling the maximum load of 250 tons. For this purpose an equalizer is provided which carries a 250-ton hook and is connected by heavy pins to the hooks of the 125-ton blocks. (Fig. 16.) In actual tests 312 tons were lifted, equivalent, roughly, to the weight of 4500 persons. These blocks are suspended by ropes passing over sheaves located at the fixed point of the jib, the reach being varied by luffing the jib.

The Foundation

The crane foundation is formed by a circular box girder having concentric web plates spaced 4 ft. apart with a mean diameter of 60 ft. This girder is securely built into the hull of the ship and a top flange projects about 2 ft. above the deck and is provided with a heavy cover plate forming a plane surface upon which the crane runway is mounted. This runway consists of four rings of 150-lb. rails spaced in pairs over the webs of the foundation girder. The rails are supported on cast-steel radial chairs secured to the girder and provided with wedges so that the elevation of the rails may be properly adjusted. In order to permit the rotation of the crane about its center pin without undue friction, the rails are so elevated that the centers of their heads are located on the elements of two cones having their apex at the center of rotation.

The usual method of operating cranes of this type is by rollers. In this case, however, the diameter of the runway was so large and the loads carried so great that it would have been impossible to retain the rigidity of the track necessary for roller operation. Because of this, a novel construction was evolved, the crane rotating on double-tread cast-steel wheels approximately 30 in. in diameter with treads finished to diameters corresponding to the rolling cones, one side of the cone being, of course, somewhat higher than the other, with a corresponding variation in the elevation of the treads on the track. This may be seen from Figs. 6 and 7 which show the wheels. The wheels are arranged in pairs with each pair carried in a cast-steel equalizing-truck frame forming a truck unit. Between the trucks are provided powerful jacks capable of supporting the weight of the entire structure. When the crane is in operation the jacks are, of course, lifted off the track. When the ship is under way at sea and the crane is cradled the jacks support the weight of the structure and thus

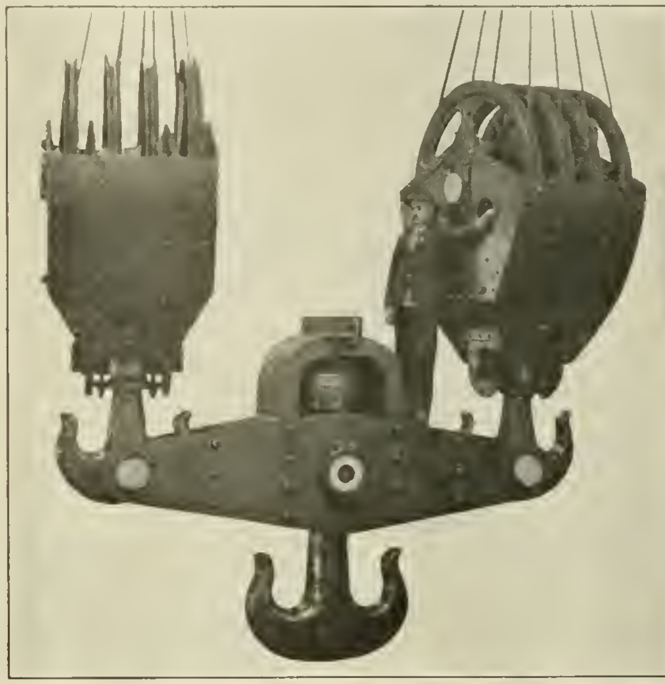

Fig. 16 With an Equalizer, the Main Hoists Handle 250 Tons

relieve the wheels from possible pounding in a rough sea, which result in the production of flats.

The main structure of the crane is built upon two box girders which are 10 ft. deep and 75 ft. long, and have webs spaced 30 in. apart. These girders are supported by the main carrying trucks, four fully equalized units being located under each end of the girders. Intermediate between the main trucks are spring-mounted truck units which are adjusted to take a part of the maximum truck load. Outrigger girders normal to the sides of the main girders are supported over four truck units for the purpose of securing side stability. The center-pin girder is built between the main girders and extends to within 2 ft. of the deck. The center pin is secured in this girder and turns in a bearing mounted in a companion girder built into the ship's hull. The center pin is hollow and the electric conductors supplying power for crane operation pass up through it to rings on the contact column above, from which the current is taken off by brushes.

The counterweight compartment is built between the main girders at the back and contains about 1,000,000 lb. of armor plate secured in place by concrete. This counterweight is proportioned so that the reverse movement with the light jib in its high position is approximately the same as the forward movement with maximum load at full reach. Back stays are built at the rear of the main girders for the purpose of supporting the back luffing nuts. These stays also serve as a support for the hoist-rope sheaves.

All the machinery for hoisting and rotating is carried by the main and outrigger girders and is completely enclosed by a circular machinery house which extends below the top of the crane foundation to form a skirt so constructed as to prevent the seas from washing over the trucks or foundation.

The Luffing Mechanism and Its Operation

From its lowest position when resting in the cradle to its highest working position the jib revolves about its hinge pins through an angle of nearly 60 deg. This movement is accomplished by large luffing screws operating through the upper and rear nuts previously mentioned. The screws are made of chrome-nickel steel and are 15 in. in diameter and 28 ft. long. Two of these screws are coupled together at the center, one having right-hand and the other left-hand threads so that their rotation tends to increase or diminish the distance between the nuts according to the direction in which they are turned. The threads of the screw are of the buttress type, 4 in. pitch, and the maximum load carried on each screw is 500 tons, which occurs with the load at maximum reach.

The design of these luffing screws was anything but an easy problem. The screws are exposed to such enormous stresses that very great strength had to be put into them and at the same time their size had to be held down as much as possible in order to reduce the weight of the screw and the size of the luffing nuts, of which more will be said later. Furthermore, the forging of a piece 28 ft. long was a difficult proposition in itself, and any increase in diameter would have materially increased the difficulty of forging. After certain tests chrome-nickel steel was selected and its use made it possible to keep the diameter of the screw down to 15 in.

Special manganese bronze is used for the luffing nuts which are about 5 ft. long, 26 in. in diameter, and weigh about 5000 lb. each. Each nut is enclosed in a cast-steel housing with trunnions turning in bearings attached to the boom and the back stay, and the design is such that when the jib is at rest on the cradle the lower nut trunnion may be slacked off, relieving the load on the screws and avoiding the possibility of excessive tension which might be produced by the deflection of the ship in a seaway. The selection of the material for these nuts was not easy, as, for obvious reasons, steel could not be used. We are informed that the bronze finally chosen has the following physical characteristics:

Ultimate strength	100,000 lb.
Yield point	60,000 lb.
Elongation	24 per cent
Brinell hardness	165

Operation of the luffing screws is controlled by a cross-shaft geared to the screw couplings by bevel gears. This shaft is turned by a spur-gear reduction to the intermediate shaft, which in turn is connected to the motor by herringbone gears. This mechanism is mounted on a machinery floor carried by a luffing strut which is pivoted to the jib midway between the jib hinge and upper luffing nut. (Fig. 17.) This strut also pivots on a large housing which encloses the screw coupling and the bevel gears midway between the upper and lower nuts.

The strut thus located forms a bisector of two legs of the triangle formed by lines joining the luffing nuts and the jib hinge, and it always maintains the same angle with the horizontal in all positions of the jib; this condition lends itself to the arrangement of the luffing mechanism as the floor of this machinery house is thus maintained horizontal at all times. This fact is also true of the auxiliary trolley mechanism, which is supported by the strut. However, on account of the fact that the relative positions of the strut and the jib are constantly varying, it is necessary to locate the trolley drum on the center of the lower pivot of the strut, which is of course a point common to both. In this location no change in length of the trolley ropes results as the jib traverses its entire range.

The maintenance of the floor of the machinery house at all times in a horizontal position as referred to above is secured in the following manner: The luffing strut at its upper end is provided with a bearing engaging trunnions on the bevel-gear housing in which the coupling for the upper and lower screws is located. This coupling is used for connecting the upper and lower screws, right and left hand, respectively, and the nuts through which the screws turn are located at equal distances on either side of the housing trunnions.

The screws are revolved to luff the jib and it is evident that any revolution of the screws through the nuts increases or diminishes the center distance. At the same time the coupling retains its position midway between the nuts. The lower end of the luffing strut is secured by pins to the jib at a point midway between the forward and upper luffing nut and the jib hinge. On account of the fact that the two points of support of the strut are always midway between the points which vary in the course of the luffing function, the strut always remains parallel to the third side of the triangle which is formed by these points, the third side in this case being the backstay. It is therefore evident that any structure forming a part of the strut or built into the strut will maintain a constant angle with the backstay or any portion of the stationary part, and thus will be maintained in a permanent angular relation to the deck.

All the functions of the crane are controlled by one operator, the various levers for this purpose being located in an elevated cab at one side of the jib.

U. S. Crane Ship No. 1—General Data

	Battleship	Crane Ship
Length	368 ft.	368 ft.
Beam	72 ft. $2^1/_2$ in.	92 ft.
Draft	23 ft. 6 in.	19 ft. 7 in.
Displacement	11,520 tons	10,350 tons
Speed	16 knots	11 knots
No. of vertical triple-expansion engines	2	1

Speeds of Hoists

Main hoist loaded	6 ft. per min.
Main hoist empty	16 ft. per min.
Auxiliary hoist loaded	15 ft. per min.
Auxiliary hoist empty	30 ft. per min.
Auxiliary trolley	50 ft. per min.
Luffing from high to low position	25 min.
Rotating one revolution	9 min.

Ranges of Operation

Main Hoists:

Radius: Between 72 ft. and 101 ft. from center of rotation.

Vertical Range: From 103 ft above to 40 ft. below rails on which crane revolves.

Auxiliary Hoist:

At 114 ft. radius the auxiliary hook has a vertical range from 135 ft. above the rails to 40 ft. below. With the jib in its highest position the upper vertical range of the auxiliary hoist is increased to 147 ft. at 91 ft. radius, and the maximum reach with the jibs in a horizontal position is approximately 173 ft. from the center of rotation. The maximum range of the auxiliary hoist is 175 ft.

Prevention of Accidents Due to Rolling of Ship

One of the important problems in the design of this crane was to so proportion its members that they would not only sustain the working load but would withstand the strain and impacts resulting from the rolling and pitching of the ship when at sea, and elaborate means are provided to protect the machine from any damage arising from this cause.

Heavy jackscrews are provided between the truck units. These jacks may be set to relieve the wheel loads and prevent pounding which might result in flat wheels. Each side of the crane has large turnbuckles for securing the crane structure to the hull, and the rear of the crane is provided with a socket into which a forged-steel locking pin is inserted to prevent the rotation of the structure as the ship rolls from side to side. The cradle in which the jib rests is fitted with heavy steel shoes and provided with clamps for holding the jib in position. A cradle is also provided for receiving the hoist blocks and equalizer when not in use.

The Hoisting Machinery

The main hoist machinery consists of two units, each having a capacity of 125 gross tons. The drums (Fig. 9) forming a part of this mechanism are 86 in. in diameter and 8 ft. 4 in. long arranged in tandem, each drum being provided with a driving gear meshing with a common pinion carried on a shaft between the drums.

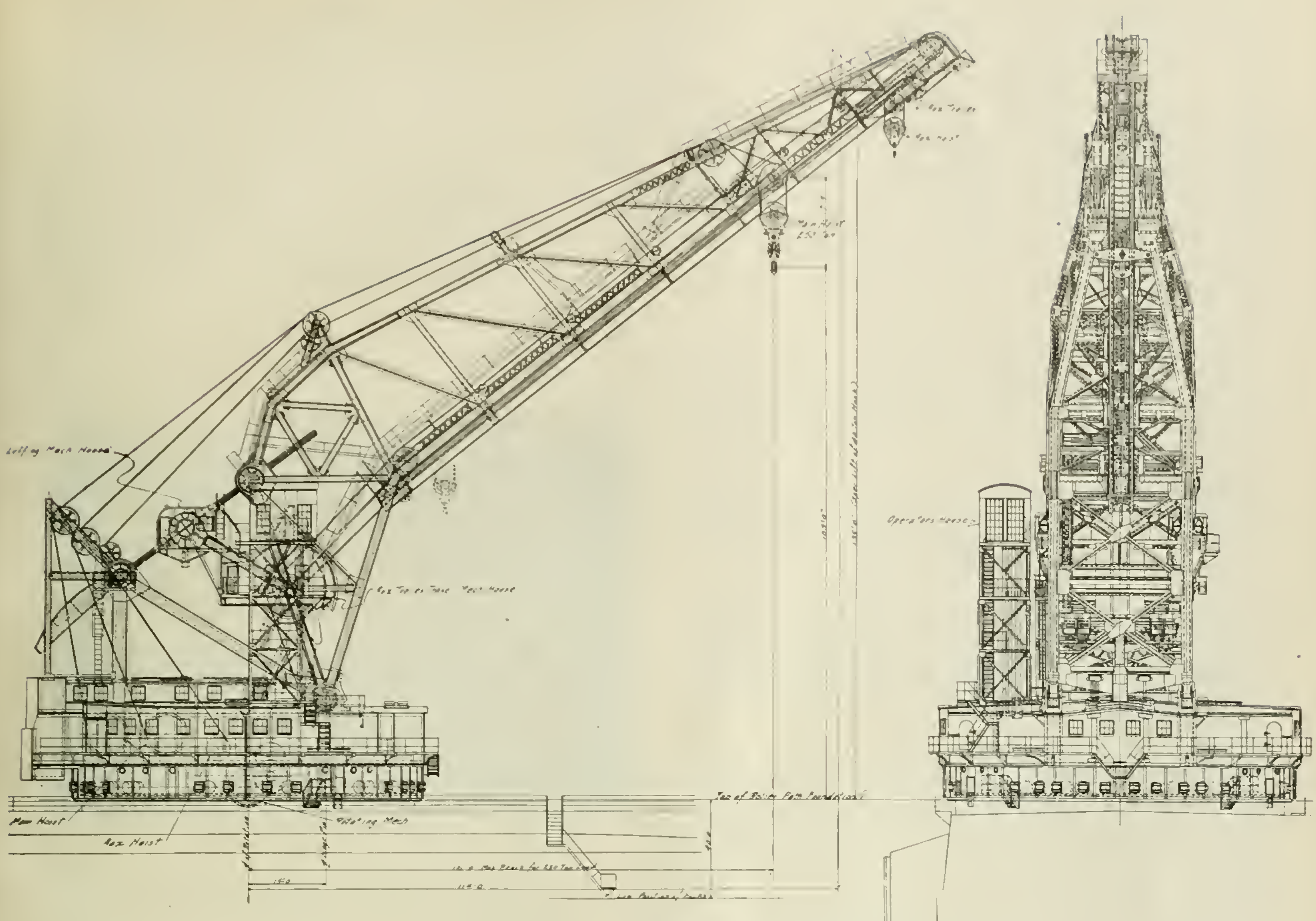

Fig. 17 The Crane Design Involves Severe Problems

Severe mechanical and structural problems were involved in the design of a crane to handle over three hundred tons on the main hoist and fifty tons on the auxiliary hoist between the limits shown in Fig. 17. Note particularly the isosceles triangle with the jib post as one of the equal sides, the inclined foundation member as the other, and the luffing screws as the base. The connection between the middle point of the jib post and the luffing nuts is always parallel to the inclined foundation member, and the floor of the luffing-mechanism house is always horizontal.

The drums and driving gears of these units are located between the main gears of the crane. The drums stand on their supporting shafts which are carried in bearings secured to a common bed plate. This bed plate is in turn carried by a substantial structural foundation built into the crane structure.

The pinion shafts of the two hoist units are in accurate alignment and a jaw clutch is provided at the center to connect the two units when handling the 250 tons on the equalizer.

Midway between the curved rails upon which the trucks travel is a bevel-gear rack used for rotating the crane. (Fig. 7.) The pitch diameter of this rack is 61 ft. The teeth are 20 deg. involute in form and have a pitch of about 9 in. The rack is made in sections which are bolted to the rail chairs.

Meshing with the rack are two pinions located diametrically opposite at each side of the revolving structure. (Fig. 8.) These pinions have 12 teeth 20 deg. involute in form and are half-shrouded. They are keyed to separate shafts which are driven through two reductions of spur gears and a motor train of cut herringbone gears by a 110-hp. General Electric motor. The motor and first intermediate shaft are mounted on a cast-steel bed plate in the machinery house, while the second and third shafts are below the floor girders. Each motor pinion is fitted with a magnetic disk brake and connected to the motor by a flexible coupling. Double-acting equalized post brakes are provided on each unit operated by a single lever in the cab. There is no mechanical connection between the two rotating units, as the series characteristics of the motors equalizes the load on the two pinions.

Although the motor brakes when set will normally resist any tendency to rotate, as an additional precaution a heavy locking pin is provided which is inserted by a hand-operated mechanism into a socket in the under side of the counterweight compartment at the rear of the structure. This pin is of forged steel 14 in. by 12 in. and is operated by a screw-toggle arrangement and a handwheel. The mechanism is located in the transverse girder attached to the deck of the ship, and of such a height that the rotating structure just clears in passing.

Four 4-in. turnbuckles are provided at the outer ends of outrigger girder. When the crane is not working or preparing for a sea voyage, these turnbuckles are secured to socket castings attached to the crane foundation to prevent any movement when the ship is rolling.

The luffing mechanism is located in a house built into the upper end of the luffing strut between the screws. The upper end of the strut is provided with heavy strap castings which surround trunnions on the bevel-gear housings. These housings are made in halves and enclose the bevel gears and pinions which turn the luffing screws. The bevel gears are bolted to flanges of nickel-steel couplings, used to connect the upper and lower luffing screws, which are tightly fitted into sockets in the ends of the couplings and secured by wedged keys. The screws are 15 in. in diameter and have a 4-in. pitch thread. One right-hand and one left-hand screw are used on each side of the crane for luffing the jib. The combined length of the two screws and their coupling is 83 ft., and their weight about 45,000 lb. The lower base of the housing forms a thrust bearing against a shoulder on the coupling to maintain the luffing strut in position.

The bevel pinions driving the coupling gears are keyed to opposite

(Continued on page 399)

Orifice Coefficients—Data and Results of Tests

By JACOB M. SPITZGLASS,[1] CHICAGO, ILL.

This paper discusses the results of experimental work conducted at the Research Laboratory of the Republic Flow Meters Co., of Chicago, on the use of orifice plates for measuring the flow of fluids in pipes.

Extensive tests were carried on for a period of several years to determine the effect of the varying factors such as the orifice ratio, the size of the pipe, and the distance of the upstream and downstream connections upon the pressure difference across the orifice plate. The tests were conducted on seven sizes of pipes, from 2-in. to 12-in. standard. Fourteen orifice ratios were used in each size and twelve connections were tested on each side of the orifice plate.

The tests were made on the flow of atmospheric air, supplied by a Sturtevant blower driven by a 15-hp. motor and having a maximum capacity of 6000 cu. ft. per min., at a pressure of 10 in. of water. To vary the velocity of flow, an adjustable air gate was attached to regulate the intake to the blower. The air passing through the orifice was measured by five calibrated impact tubes ranging from 1 in. to 4 in. in internal diameter.

The theoretical relations of the functions are given briefly, preceded by definitions of the terms involved. The paper includes a number of tables and a collection of characteristic curves that may be employed for determining the flow through orifice plates in a given size of pipe.

IT HAS been long established in the literature of mechanical engineering, and especially in the various textbooks on hydraulics, that a stream of fluid issuing from a rounded aperture in the wall of a large vessel can be gaged accurately by the difference in static pressure between the inside and the outside of the vessel containing that fluid.

The relation between the pressure difference and the velocity of the jet issuing from the aperture has been derived theoretically for jets flowing into the open atmosphere and also for jets submerged under a lower head of the same fluid. It has been established by numerous experiments that upon leaving the vessel the cross-section of the stream is gradually reduced in area until, at a point known as the vena contracta, it is only about 60 per cent of the actual area of the aperture in the wall of the vessel. This contrivance used as a device for measuring the flow of fluids has been termed the "frictionless" or "thin-plate" orifice.

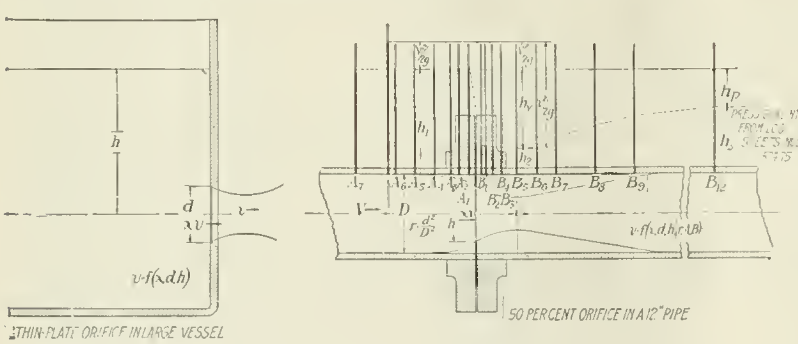

Fig. 1 Thin-Plate Orifice—Jet Contraction and Pressure Gradient

Recently the principle of the thin-plate orifice has been successfully applied to measuring the flow of fluids in pipes by the drop of pressure through the restricted area of an orifice plate placed between two flanges of the given pipe. At first the practice was limited entirely to cases where the area of the opening was much smaller than the cross-section of pipe, so that they could be considered as being similar to the submerged aperture in the wall of a large vessel. Further developments in this application have necessitated the use of larger-ratio orifices, which obviously differ from the case of the jet issuing from the large vessel, and therefore cannot be treated in the same manner. A comparison of the two cases with reference to Fig. 1 brings out the following points of difference:

First, in the case of the thin-plate orifice in the large vessel, the velocity of the jet issuing from the wall represents the equivalent of the hydrostatic head or pressure above the center of the opening, since the fluid in the vessel may be considered to be at rest. In the case of the pipe orifice it is the increase in velocity over the velocity of approach that is equivalent to the differential head across the orifice. This item may be termed the effect of initial velocity in the pipe.

Second, in the case of the pipe orifice the formation of the stream may be greatly affected by the proximity of the walls of the pipe both on entering and on leaving the orifice. In the case of the large vessel this effect is eliminated on either side of the orifice and the stream of the fluid can be freely formed into the natural contraction of the issuing jet. This item may be termed the effect of the size of the pipe or of the proximity of the walls.

Fig. 2 Interior of Research Laboratory

Third, in the case of the large vessel the pressure difference affecting the flow of the fluid is fixed by the difference between the pressure inside and outside the vessel. In the case of the pipe orifice it is necessary to obtain the pressure difference between a point ahead of the orifice where the current is parallel to the walls of the pipe and a point beyond it where the jet has been fully contracted, in order to have the true equivalent of the increased velocity pressure of the jet. This may be termed the effect of shifting the pressure taps on either side of the orifice.

These given points of difference are demonstrated graphically in Fig. 1 to show their relations to the dimensional quantities involved. Thus, the effect of initial velocity is a function of the relation between the velocity V of the fluid in the pipe and the velocity v of the jet at the point of greatest contraction, or of the ratio d^2 D^2 between the cross-sections, which, in its turn, is a function of the jet contraction x and of the ratio between the cross-section of the orifice and the cross-section of the pipe. The effect of restriction or the proximity of the walls is a function of the distance between the wall of the pipe and the edge of the opening, which, in its turn, is a function of the diameter D of the pipe for any given orifice ratio. The effect of shifting the pressure taps is necessarily a function of the location of the taps on the A and B sides of the orifice plane.

The experimental work described in the complete paper was undertaken with the object of obtaining the necessary data for this analysis: namely, to determine by actual tests the effect produced in the pipe orifice, used as a flow-measuring device, by the variation of the orifice ratio, by changing the size of the pipe, and by shifting the pressure taps on either side of the orifice plate.

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Contributed by the Research Committee and presented at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. Abridged. All papers are subject to revision.

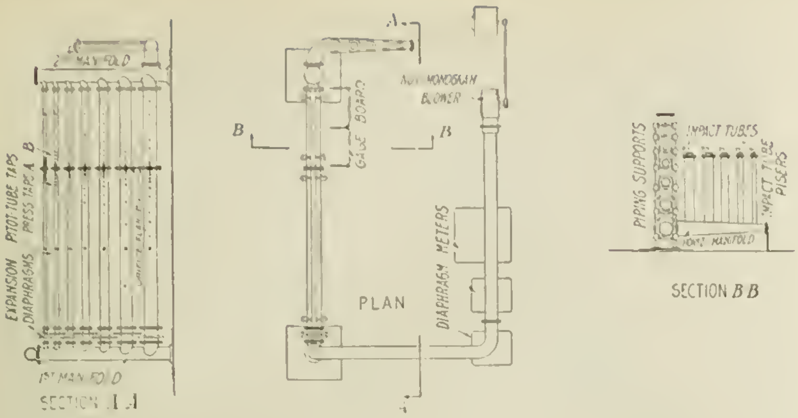

Fig. 3 General Layout of Research Laboratory Equipment

The Tests

In the early part of 1919 the engineering department of the Republic Flow Meters Company began its first series of orifice tests on several sizes of pipes. On the removal of the company to its new headquarters in 1920, a research laboratory was established on the second floor of the factory building for the purpose of furthering the experimental work on orifice coefficients. Fig. 2 is a view of this laboratory and Fig. 3 shows the general arrangement of apparatus as originally installed.

Extensive tests were carried on to determine the effect of the varying factors such as the orifice ratio, the size of the pipe, and the distance of the up-stream and down-stream connections upon the pressure difference across the orifice plate. The tests were conducted on seven sizes of pipes, from 2-in. to 12-in. standard. Fourteen orifice ratios were used in each size and twelve connections were tested on each side of the orifice plate.

The tests were made on the flow of atmospheric air, supplied by a Sturtevant blower having a maximum capacity of 6000 cu. ft. per min. at a pressure of 10 in. of water. The air passing through the orifice was measured by five calibrated impact tubes ranging from 1 in. to 4 in. in internal diameter. A detailed account of the calibration of the impact tubes is given in the complete paper, as well as curves showing the coefficient as a function of the impact head through the tube. The arrangement of the installation for the final tests is also described and illustrated in detail, and an account is given of the method of testing the various orifices.

Theoretical Relations of Functions

The following notation is adopted with reference to Fig. 1, in which most of the quantities and dimensions are demonstrated diagrammatically.

- d = diameter of the thin-plate orifice, either in the restricted pipe or in the wall of the large vessel
- D = diameter of pipe
- x = percentage of jet contraction at the smallest cross-section or the vena contracta of stream
- r = ratio of orifice cross-section to pipe cross-section, or d^2/D^2; xr = ratio of vena contracta to cross-section of pipe
- ρ = $1/r$ = ratio of pipe cross-section to orifice cross-section or D^2/d^2; ρ/x = ratio of pipe cross-section to the vena contracta of stream
- A = distance from plane of orifice to upstream pressure taps
- B = distance from plane of orifice to downstream pressure taps
- h_1 = static pressure at section of normal flow ahead of orifice
- h_2 = static pressure at section of vena contracta
- h_3 = static pressure at section of normal flow beyond orifice
- h = differential head between any two points on opposite sides of the orifice
- h_v = differential head between the two points designated as h_1 and h_2. This quantity represents the pressure drop across the orifice corresponding to the increased velocity of the flow
- h_p = differential head between the two points designated as h_1 and h_3. This quantity measures the total loss of pressure caused by the sudden contraction and expansion of the flow through the orifice
- Z = ratio of h_p to h_v
- V = velocity of fluid at section of normal flow in pipe
- v = velocity of fluid at vena contracta of stream
- xv = velocity of fluid at section of orifice
- Q = rate of flow or amount of fluid passing through the orifice in a given unit of time
- C = coefficient of discharge defined by

$$Q = C\frac{\pi}{4}\frac{d^2}{\sqrt{1-r^2}}\sqrt{2gh} = C\frac{\pi}{4}\frac{D^2}{\sqrt{\rho^2-1}}\sqrt{2gh} \qquad [1]$$

C' = velocity coefficient of orifice defined by—

$$v = C'\sqrt{2gh}, \text{ and } C' = f(A)f(B)\sqrt{\frac{1}{1-x^2r^2}} \qquad [2]$$

(xC') = orifice coefficient defined by—

$$Q = (xC')\frac{\pi}{4}d^2\sqrt{2gh} \qquad [3]$$

C'' = orifice coefficient defined by—

$$Q = C''\frac{\pi}{4}D^2\sqrt{2gh}, \text{ or } C'' = (xC')r \qquad [4]$$

Derivations of Equations [1] to [4] defining C, C', and C'' are given in the complete paper. Subscript v, with reference to the given terms, applies to the condition of pressure tap A at normal flow ahead of the orifice plane and pressure tap B at the vena contracta. Subscript p applies to the condition of pressure tap A at normal flow ahead of the orifice plane, and pressure tap B at normal flow after the orifice plane.

The quantity C in Equation [1] is the coefficient of discharge for the orifice as compared with the coefficient of discharge for the venturi tube. In using this coefficient it is always necessary when solving Equation [1] to compute the radical $\sqrt{1-r^2}$ for the given orifice ratio. This is especially troublesome when a solution is sought for the size of the orifice necessary for a given differential and amount of flow, as it involves two unknown quantities C and

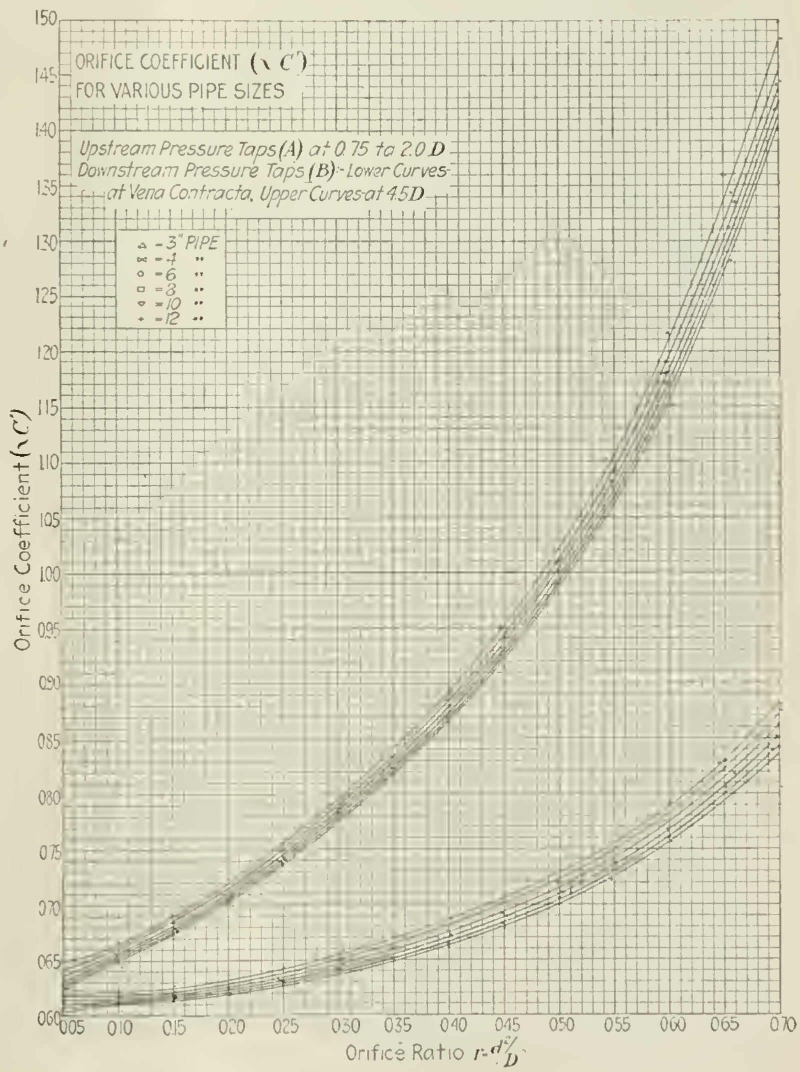

Fig. 4 Orifice Coefficients for Various Pipe Sizes

r. To overcome this difficulty, a modification of Equation [3] is employed with reference to the cross-section of the pipe. Since $d^2 = D^2r$, we can write—

$$Q = (xC')r\,\frac{\pi}{4}\,D^2\sqrt{2gh}$$

or—

$$Q = C''\,\frac{\pi}{4}\,D^2\sqrt{2gh}$$

This equation in combination with a C''-r curve gives a direct solution for the size of orifice necessary for a given flow.

The pressures h_1, h_2, and h_3 at the three main sections of the orifice region are significant for the fact that they indicate the relation between the drop of pressure h_v equivalent to the increase in velocity and the pressure loss h_p caused by the sudden contraction and expansion of the flow. From the above equations, we can write—

$$C_p\sqrt{h_p} = C_v\sqrt{h_v}$$

from which—

$$\text{Fraction of loss } Z = \frac{h_p}{h_v} = \left(\frac{C_v}{C_p}\right)^2 \ldots\ldots [5]$$

$$\text{and fraction of pressure restoration} = 1 - Z = 1 - \frac{h_p}{h_p} = 1 - \left(\frac{C_v}{C_p}\right)^2.$$

The same applies to any of the experimental coefficients determined for the two sections corresponding to h_2 and h_3, respectively.

Computation of Results

The method adopted was to compute the rate of flow in pounds per minute for the calibrated impact nozzles used as a standard,

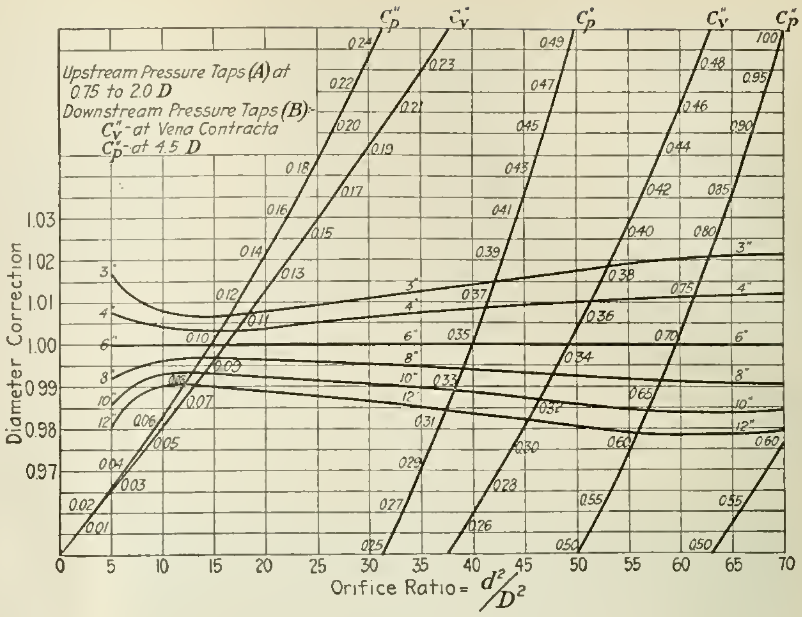

Fig. 6 Orifice Coefficient C'' for 6-in. Pipe and Correction Factors for Other Sizes

and the rate in pounds per minute derived theoretically for the given orifice plate, assuming xC' to be equal to unity. The actual value of the coefficient xC' for the given orifice is necessarily the ratio of the former to the latter. The method of procedure is demonstrated on the sample log sheets in the complete paper which contain the data of one A-run and one B-run on the 12-in. pipe.

The data of the final tests are recorded on 1625 log sheets filed in chronological order and cross-indexed under the various headings of impact tube, pipe size, and orifice ratio. A log sheet of the impact-tube tests contains a run on a given tube either varying the velocity head at constant setting or the setting at constant velocity. A log sheet of the orifice tests contains a run on a given-ratio orifice at constant velocity either varying the upstream A-taps with the downstream constant, or the downstream B-taps with the upstream constant. A complete test for a given orifice ratio comprises four velocity tests and from five to twelve log sheets for each velocity, part of them with A constant and B varying, and part with B constant and A varying. Each pipe size was tested for fourteen orifice ratios with the exception of the 2-in. pipe, on which the lower-ratio orifices were not completed at the writing of this paper.

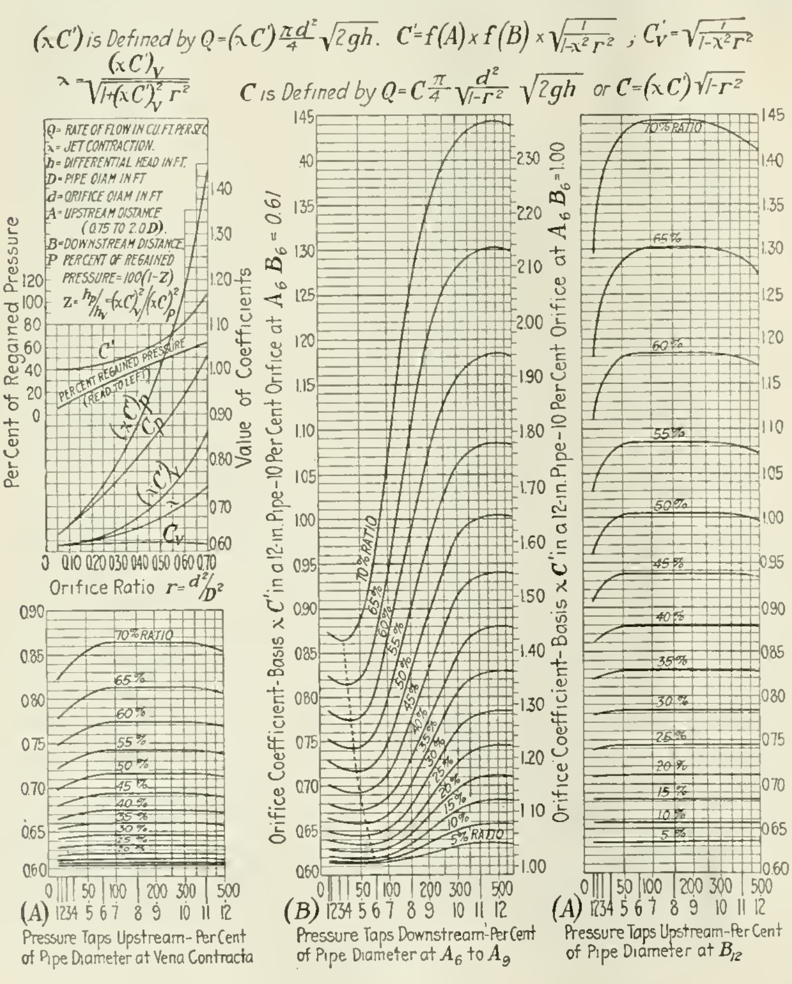

Fig. 5 Characteristic Curves for Orifice Plates

Characteristic Curves of Orifice Plates

At the completion of a test for a number of orifice plates in a given size of pipe the values of the coefficient xC' were plotted in three sections on large sheets ruled in logarithmic coördinates. The first section represented the so-called A-curves plotted as a function of the upstream distances from the A-runs of the test with the downstream connection at the vena contracta. The second section represented the B-curves plotted as a function of the down-stream distances from the B-runs of the test. The third section consisted of A-curves plotted as a function of the upstream distances with the downstream connection at four and one-half diameters of the pipe or the point of complete restoration of pressure.

These curves, not given in the paper, represented in substance the form similar to the three main sets of the final curve, shown in Fig. 5 for the 10-in. pipe, except that in the original curves each orifice ratio was represented by a group of lines adjoining the test points of the several velocities for a given ratio. Also in those curves the actual orifice ratios were used, which differed somewhat from the equal divisions of the final curves in Fig. 5. With small exceptions the lines of each group did not

deviate much from each other, so that in each case a single line was drawn which represented the average value of the coefficient for the given ratio.

From these average lines the points of minimum and maximum were plotted on Fig. 4 as a function of the orifice ratio for the various sizes of pipe, the lower set for the coefficient $(xC')_v$ at the vena contracta, and the upper set for the coefficient $(xC')_p$ at four and one-half diameters from the orifice plate. After the points of the two sets on Fig. 4 were joined by smooth lines for the given sizes of pipes, the corrected values were obtained for the even ratios in multiples of five and the points transferred to the original curves and compared with the average lines of the nearest ratio. A new line was drawn parallel to the old one to pass through the corrected points for the even ratio. In this manner the effects of possible errors of observation were reduced, first, by comparison with the similar tests of the same ratio, second, by comparison with the similar tests of various ratios of the same size of pipe, and third, by comparison with the similar tests of the various sizes of pipes.

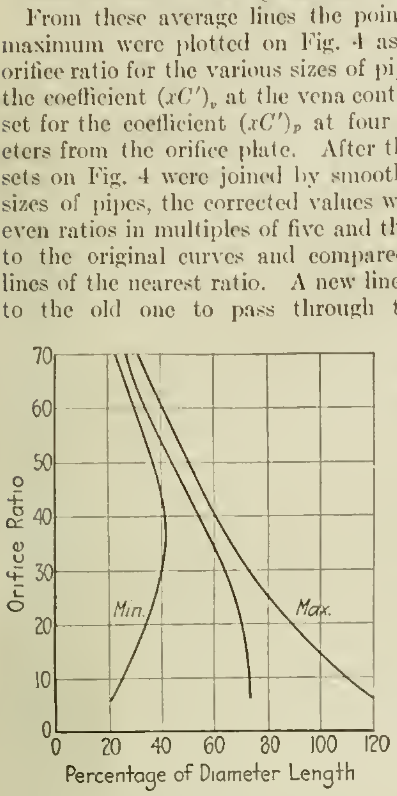

Fig. 7 Spacing of Taps at Vena Contracta

The final curves for the even ratios of the 6-in. pipe are shown in the three main sections of Fig. 5. These three sections give a generalization of the complete work for the given size of pipe. They point out forcibly the great importance that must be attached to the proper spacing of the orifice connections. In fact, they would seem to indicate that an excessive precision is necessary in determining these points, since a very small change in the tap distance along the steeper parts of the curves might cause a change of several per cent in the value of the coefficient.

To eliminate possibility of large errors in the practical application of the orifice, it is best, therefore, to select only those points for use at which a slight change in the position of the tap would not appreciably affect the coefficient. This condition is obviously fulfilled at the minimum and maximum points, since these points occur at the flat portion of the curve.

The A-curves given are restricted to as study of conditions at these two points. These two sets can be used in a similar manner to select the proper points at which to place the upstream pressure taps. Thus, since the flat parts of the curve occur between points A_6 and A_9, the upstream pressure taps should always be located between these points for the practical application of the orifice.

The curves in the upper left-hand section of Fig. 5 fulfil both of these conditions selected for good practice, that is, the upstream connections are always between 0.75 D and 2.00 D, and the downstream connections are at the vena contracta or at four and one-half diameters of the pipe. In this section are plotted as a function of the orifice ratio the values of xC', x, C', C and also the percentages of pressure restoration in the pipe. The values of these coefficients are given in Tables 1 to 6 for the various sizes of pipe.

The selection of the upstream and downstream distances to be used in general practice must not be taken as a limitation on the use of the orifice to these few points. With the proper care in spacing the pressure taps the coefficient corresponding to the exact distance can be easily and precisely obtained from the characteristic curve for the given pipe size.

TABLE 1 ORIFICE COEFFICIENTS FOR 12-IN. PIPE

Ratio $r = \frac{d^2}{D^2}$	$(xC')_v$	$(xC')_p$	x	C'	C_v	C_p	1–Z
5	0.603	0.624	0.603	1.000	0.603	0.624	0.067
10	0.610	0.650	0.609	1.002	0.607	0.617	0.119
15	0.614	0.676	0.612	1.003	0.607	0.668	0.174
20	0.620	0.703	0.615	1.008	0.608	0.689	0.223
25	0.627	0.736	0.619	1.013	0.608	0.714	0.274
30	0.637	0.774	0.626	1.018	0.608	0.739	0.326
35	0.649	0.818	0.633	1.025	0.608	0.767	0.371
40	0.663	0.867	0.641	1.034	0.608	0.795	0.416
45	0.679	0.923	0.649	1.046	0.606	0.824	0.459
50	0.700	0.987	0.661	1.059	0.606	0.855	0.497
55	0.725	1.063	0.674	1.076	0.605	0.887	0.535
60	0.756	1.157	0.689	1.097	0.605	0.926	0.573
65	0.795	1.273	0.706	1.126	0.605	0.968	0.610
70	0.846	1.413	0.728	1.162	0.604	1.010	0.641

TABLE 2 ORIFICE COEFFICIENTS FOR 10-IN. PIPE

Ratio $r = \frac{d^2}{D^2}$	$(xC')_v$	$(xC')_p$	x	C'	C_v	C_p	1–Z
5	0.606	0.627	0.606	1.000	0.606	0.627	0.066
10	0.611	0.652	0.610	1.002	0.608	0.649	0.122
15	0.615	0.678	0.612	1.005	0.608	0.670	0.177
20	0.621	0.705	0.616	1.008	0.609	0.691	0.224
25	0.630	0.738	0.622	1.013	0.611	0.715	0.271
30	0.640	0.777	0.629	1.018	0.611	0.742	0.321
35	0.651	0.821	0.634	1.026	0.610	0.769	0.371
40	0.665	0.870	0.642	1.035	0.610	0.797	0.416
45	0.683	0.926	0.653	1.046	0.610	0.827	0.456
50	0.701	0.992	0.664	1.060	0.610	0.859	0.496
55	0.730	1.069	0.677	1.074	0.609	0.893	0.534
60	0.761	1.165	0.692	1.099	0.601	0.932	0.573
65	0.800	1.281	0.710	1.127	0.608	0.974	0.610
70	0.851	1.420	0.728	1.163	0.608	1.014	0.641

TABLE 3 ORIFICE COEFFICIENTS FOR 8-IN. PIPE

Ratio $r = \frac{d^2}{D^2}$	$(xC')_v$	$(xC')_p$	x	C'	C_v	C_p	1–Z
5	0.610	0.631	0.610	1.000	0.610	0.631	0.065
10	0.613	0.654	0.611	1.003	0.610	0.651	0.120
15	0.618	0.680	0.615	1.005	0.611	0.672	0.175
20	0.624	0.708	0.619	1.008	0.612	0.694	0.223
25	0.632	0.741	0.624	1.013	0.613	0.718	0.272
30	0.643	0.780	0.631	1.019	0.614	0.744	0.320
35	0.655	0.825	0.638	1.027	0.614	0.773	0.369
40	0.670	0.874	0.646	1.035	0.614	0.801	0.412
45	0.688	0.931	0.657	1.047	0.614	0.831	0.451
50	0.710	0.997	0.669	1.061	0.614	0.863	0.493
55	0.736	1.076	0.682	1.079	0.614	0.898	0.532
60	0.767	1.173	0.697	1.100	0.614	0.939	0.572
65	0.806	1.290	0.714	1.129	0.613	0.982	0.609
70	0.856	1.430	0.734	1.166	0.612	1.021	0.641

In an earlier paragraph the orifice coefficient C'' was mentioned as affecting the simplest solution of orifice problems since it relates directly to the known section of the pipe D^2. Accordingly, Fig. 6 was prepared in a convenient form for ordinary use, giving values of C''_v and C''_p as a function of the ratio. To eliminate the necessity of repeating the curves for each size, only those for the 6-in. pipe were prepared, and additional lines were drawn to scale giving correction factors to be used in obtaining the coefficient for the other pipe sizes.

Fig. 7 shows the spacing of pressure taps at the vena contracta in percentage of the diameter length corresponding to the given orifice ratio. The center line is a duplicate of the one passing through the minimum points of the characteristic B-curves in Fig. 5. The two outside curves, marked "min." and "max.," show the limits to which the tap may be shifted without varying the coefficients more than 0.25 per cent either way. The actual spacing

TABLE 4 ORIFICE COEFFICIENTS FOR 6-IN. PIPE

Ratio $r = \frac{d^2}{D^2}$	$(xC')_r$	$(xC')_p$	x	C'	C_v	C_p	1–Z
5	0.615	0.636	0.615	1.000	0.615	0.636	0.065
10	0.615	0.657	0.614	1.002	0.612	0.654	0.123
15	0.620	0.683	0.618	1.003	0.613	0.675	0.175
20	0.626	0.711	0.621	1.008	0.614	0.698	0.225
25	0.635	0.745	0.627	1.013	0.615	0.722	0.273
30	0.646	0.784	0.634	1.020	0.616	0.748	0.320
35	0.659	0.829	0.642	1.027	0.618	0.777	0.368
40	0.674	0.880	0.650	1.037	0.618	0.807	0.413
45	0.693	0.933	0.662	1.047	0.619	0.838	0.455
50	0.716	1.001	0.674	1.062	0.620	0.870	0.487
55	0.742	1.084	0.687	1.081	0.619	0.905	0.531
60	0.774	1.183	0.702	1.103	0.619	0.947	0.572
65	0.813	1.301	0.719	1.131	0.618	0.990	0.609
70	0.864	1.444	0.739	1.170	0.617	1.031	0.642

TABLE 5 ORIFICE COEFFICIENTS FOR 4-IN. PIPE

Ratio $r = \frac{d^2}{D^2}$	$(xC')_r$	$(xC')_p$	x	C'	C_v	C_p	1–Z
5	0.619	0.642	0.619	1.000	0.619	0.642	0.070
10	0.617	0.661	0.616	1.002	0.614	0.658	0.130
15	0.622	0.686	0.620	1.003	0.615	0.678	0.177
20	0.628	0.716	0.624	1.007	0.616	0.702	0.231
25	0.638	0.750	0.630	1.013	0.618	0.727	0.276
30	0.650	0.790	0.638	1.019	0.620	0.754	0.323
35	0.662	0.835	0.645	1.027	0.621	0.782	0.371
40	0.680	0.886	0.656	1.037	0.623	0.812	0.411
45	0.700	0.946	0.668	1.048	0.625	0.845	0.452
50	0.723	1.014	0.680	1.063	0.626	0.878	0.491
55	0.750	1.096	0.693	1.083	0.626	0.915	0.531
60	0.782	1.197	0.708	1.105	0.626	0.958	0.572
65	0.820	1.318	0.723	1.135	0.624	1.002	0.613
70	0.873	1.464	0.745	1.172	0.624	1.045	0.644

TABLE 6 ORIFICE COEFFICIENTS FOR 3-IN. PIPE

Ratio $r = \frac{d^2}{D^2}$	$(xC')_r$	$(xC')_p$	x	C'	C_v	C_p	1–Z
5	0.624	0.649	0.624	1.000	0.624	0.649	0.074
10	0.619	0.663	0.618	1.002	0.616	0.660	0.125
15	0.623	0.688	0.621	1.003	0.616	0.680	0.179
20	0.631	0.718	0.626	1.008	0.619	0.704	0.227
25	0.641	0.754	0.633	1.013	0.621	0.731	0.277
30	0.653	0.795	0.641	1.018	0.623	0.759	0.325
35	0.668	0.841	0.651	1.026	0.626	0.789	0.369
40	0.684	0.893	0.660	1.036	0.627	0.818	0.413
45	0.705	0.953	0.672	1.049	0.629	0.853	0.453
50	0.728	1.022	0.684	1.064	0.630	0.885	0.492
55	0.756	1.106	0.698	1.083	0.631	0.923	0.532
60	0.788	1.210	0.713	1.106	0.630	0.968	0.575
65	0.827	1.331	0.728	1.136	0.629	1.012	0.615
70	0.880	1.480	0.749	1.175	0.629	1.057	0.626

should be made as nearly as possible to that given by the center curve, since it is drawn to indicate the exact position of the vena contracta.

Conclusion

The scope of this paper will not permit of going into the particular details of each individual test. Its main object is to present the results obtained in the research laboratory in such a form that they can be applied conveniently.

A few remarks may be in order about the most salient points brought out by this investigation.

The orifice plate used as a measuring device for the flow of fluids in pipes has a relative accuracy well within the limit of 2 per cent. If reasonable care is applied in the selection of the location, the proper spacing of the pressure taps, and the proper centering of the orifice between the flanges in the pipe, the possible deviation may be reduced to less than 1 per cent. The maximum variation from the average in any single test seldom exceeded 1 per cent when the differential pressure was above 1 in. of water.

The loss of head through the entire region affected by the orifice, which is the differential to the point of complete restoration, is an accurate function of the velocity squared—the same as that of the drop of pressure to the vena contracta. This means that the coefficient C_p is just as reliable as the coefficient C_v. In cases where the pressure difference has an appreciable value it is even better to use the point of restoration, as the curve is much flatter at that point, in the case of large-ratio orifices, and a deviation from the proper section will not result in any appreciable error.

The coefficient of discharge C_v is shown to be very nearly constant for orifices of all ratios. This would mean that the orifice can be treated as a venturi, using the same value of C_v and correcting for initial velocity of approach the same as is done in the venturi tube.

The jet issuing from the orifice does not contract to the same extent in the smaller sizes of pipes. This is probably due to the fact that the portion of the flow which is restricted by the orifice has a proportionately lower velocity due to the increased skin friction in smaller sizes of pipes.

The variation of velocity pressure from 100 to 300 per cent does not affect the value of the coefficient. This seems to indicate that the name "frictionless orifice" is not misleading. For this reason it is best to use very thin material for the orifice plate to eliminate the friction at the sides of the opening. If the material has to be heavier, it is advisable to bevel the *downstream* side of the opening.

The regained head increases very rapidly with the increase of orifice ratio, making the larger-ratio orifice more applicable to cases where the loss of pressure is an important item.

Reference is made to the fact that the characteristic curves given in this paper are based upon the assumption that the coefficient of discharge for a 10 per cent orifice in a 12-in. pipe is equal to 0.61. This assumption, however, is borne out by the results of previous experiments by many authorities and can be further substantiated by additional volumetric tests at this point. The experiments, as demonstrated in this work, have shown that the orifice plate is relatively accurate for measuring the flow of fluids for the varying sizes of pipes and the various ratios of orifices at the proper spacing of the pressure taps. The characteristics curves given in the paper have a complementary scale with the basic value of 0.61 as unity, so that if further experiments should prove that the 10 per cent orifice in a 12-in. pipe has a value somewhat different from the one given, these curves can be applied in the same manner to the new value of the standard.

Discussion[1]

R. J. S. Pigott[2] wrote that the paper was especially interesting in that the values obtained and the characteristics of the stream, when taken in conjunction with the dimensional analysis given in the Fluid Meters Report, afforded a means of coördination of practically all of the experimental work on disk orifices. Heretofore these experiments had been thought to show considerable variation from each other, but when allowance was made for the difference of location in upstream and downstream taps, the ratio of orifice sizes, pipe sizes, and the location of vena contracta, it was found that nearly all the experiments gave coefficients substantially in agreement. Allowing for the difference of view of the various experimenters, it was very encouraging that this should

[1] These extracts from the discussion deal more particularly with those portions of the paper appearing in the preceding abridgment. The table and figure numbers are those used in the abridgment.

[2] Mechanical Engineer, Stevens & Wood, New York, N. Y. Mem. A.S.M.E.

be the case, and it was curious that the mathematical analysis of this flow prepared by Dr. Buckingham of the Bureau of Standards for the report should have predicted the characteristics of the orifice as found by Mr. Spitzglass, each working entirely without knowledge of the other's results. It was unfortunate that nearly every experimenter on both venturi tubes and the disk orifices should have used a different system of plotting and comparison; but possibly by trying all the different ways the best method would be adopted by the public who had to use them.

J. W. Hogg,[3] in a written discussion, said that it would be well to know whether the coefficient of the basic orifice, as well as the results derived from its use as a means of calibration, were applicable to steam and water, and possibly to other fluids heavier or lighter than water but possessing a different viscosity.

Fig. 7 showed that a good location for the low-pressure fitting was one-half of a pipe diameter behind the plate for ratios up to 50 per cent, therefore if the flow could be measured between this range without excessive differential head, a distance of one-half pipe diameter behind the orifice might be taken as a fixed location for the low-pressure connection.

It would be noted on Fig. 4 that the coefficient of discharge for a given ratio of areas decreased as the pipe size increased. The author stated in one of his concluding paragraphs that the jet issuing from the orifice did not contract to the same extent in the smaller size of pipe as it did in the larger, and further that this was probably due to the fact that the portion of the flow which was restricted by the orifice had proportionally lower velocity due to the increased skin friction in the small pipes. It then appeared that the ratio of the perimeter of the pipe to the area of the pipe or some other similar function could be incorporated in a equation to be used in figuring the coefficients for sizes of pipe which were entirely too large to be erected in a laboratory for experimental purposes. After this equation was determined the coefficient of discharge for these large pipes, such as 18-, 24-, and 30-in., could be easily interpolated.

It would also be noted in Fig. 4 that the two sets of coefficients depending upon whether the vena contracta or the point of restoration were used as the location of the low-pressure fitting were widely different in value, and the set of coefficients at the vena contracta might be termed low coefficients, while the set at the point of restoration might be termed high coefficients. It appeared from all the data taken in this test that sufficient was on hand to determine a set of coefficients with intermediate values with respect to the other two sets, and this set could be obtained by locating the high-pressure fitting at the point of restoration and the low-pressure fitting at the vena contracta.

A. F. Spitzglass[4] wrote that it seemed best for practical work in calculating orifices that separate curves be used for each size of pipe. The values for determining these curves could be obtained from Tables 1 to 6 by multiplying the values given in the first column for $(xC'')_v$ by the orifice ratio r.

Since the completion of the tests the objection had been raised that the Ellison gages could not be relied on to give results within the limits of accuracy necessary for laboratory work, unless calibrated individually against some absolute standard. Lest this cause reflection to be cast upon the value of the data given, it seemed necessary to explain the methods adopted to overcome this difficulty.

Each test was essentially a comparison of two similar functions of the pressure head at two different points in the stream. Neglecting the corrections applied, the coefficient varied as the square root of the ratio of the orifice differential to the head on the impact nozzle. Thus, only a relative accuracy between the two devices used for determining the pressures was necessary to give the required precision. With this in mind, tests were made on a large number of gages, checking them against each other over the complete range of their scales. Of these, three were finally selected that gave practically identical readings along the entire scale. One of these was used for obtaining the orifice differential and the other two for obtaining the head on the impact nozzle. To retain this precision it was necessary, therefore, to choose a nozzle of such a cross-section that the two gages would read on the same part of the scale. Furthermore, in averaging the results of any of the tests, most weight was given to those runs in which the two pressures were nearly identical.

George S. Hendrickson[5] wrote that the calibration curves for the impact nozzles showed that the coefficient changed when the velocity changed, due to the friction. As he understood it, the coefficient of the venturi tube was given as a constant irrespective of the velocity, and the conclusion he drew was that both could not be correct. He would ask whether coefficients of the venturi tube had shown a variation at different velocities.

All the tests had been made for a given pipe size in the same pipe by varying the orifice ratio. In commercial pipe it was safe to assume that the inside surface of different pipes would not have the same characteristics. One piece might be very smooth and another quite rough. He believed that this might affect the orifice coefficient, especially on the larger ratios and higher velocities.

C. A. Dawley[6] wrote that the arrangement of flow nozzles on manifolds as shown in Fig. 3, was unfortunate from the fact that the air flow had to make three right-angle turns within a short distance, thereby creating violent disturbances or eddies in the flow stream. This piping would naturally produce swirling or helical flow in the vertical pipes leading to the flow nozzles, and would certainly give a higher velocity on one half of the opening of the nozzle than on the other half. The net result of both of these irregularities would be to give a low, and perhaps a variable, coefficient for the nozzles. The fact that the coefficients found did not increase systematically with the diameter and that they were uncertain or variable in some instances, supported the belief that they were influenced by the conditions of installation. It would be of value if the author would explore, with a search tube, the whole area of the nozzle outlets as installed, finding the velocity across two diameters at different radii compared with that at the center, and then that the 3- and 4-in. nozzles should be installed in turn directly at the end of the 12-in. pipe in which the disk orifice was located and a further determination made on the relative coefficients.

The most important point settled by the paper was the location of the vena contracta and the point of maximum restoration of pressure beyond the disk orifice. For the range of heads covered by the author's tests, these results should stand regardless of any minor inaccuracy in the coefficients of the impact flow nozzles as found.

E. G. Bailey[7] wrote that it was unfortunate that the author had deemed it best to present the data in such form that they could not well be correlated or compared with other data previously presented to the Society on a similar subject. It was also very unfortunate that he did not have a standard or basic measurement upon which to start the comparison. The flow nozzles were calibrated on an assumed coefficient of one orifice, then the orifices were recalibrated on the basis of the flow nozzles. The same flow nozzle could not be used for all the different sizes of pipe, so that the final results were rather far from a definite absolute basis. Mr. Bailey believed the results as a whole gave coefficients too high; also that the paper showed more difference between the coefficients of different sizes of pipe than actually existed. While most of the data might be within 2 or 3 per cent of correct absolute value, he thought in the present state of the art greater accuracy was expected of the meter manufacturer. It was to be hoped that some subsequent tests could be made to substantiate or modify these absolute values as mentioned in the last sentence of the paper.

It would be interesting to know why Mr. Spitzglass had limited his test to a 70 per cent ratio orifice which was equivalent to 83.70 diameter ratio.

The use of circular concentric orifices gave no latitude as to the location of the vena contracta. This was rather annoying when high hub flanges were encountered; also when a pipe was tapped for an orifice of one capacity and later an orifice of a different capacity was to be installed. This might require retapping the connections at a comparatively short distance away, so that it could not

[3] Republic Flow Meters Co., Philadelphia, Pa. Jun. A.S.M.E.

[4] Engineer, Republic Flow Meters Co., Chicago, Ill.

[5] Sales Engineer, Republic Flow Meters Co., Chicago, Ill. Assoc-Mem. A.S.M.E.

[6] Consulting Engineer, N. J. Meter Co., Plainfield, N. J. Mem. A.S.M.E.

[7] Bailey Meter Co., Cleveland, Ohio. Mem. A.S.M.E.

be accomplished without going to another position on the circumference of the pipe. He had found it very advantageous in such conditions to use eccentric and segmental orifices.

John L. Hodgson[8] wrote that the author had repeated work which he had briefly summarized in Fig. 18 of his paper on the Commercial Metering of Air, Gas and Steam, read before the Institute of Civil Engineers in April, 1917.

Commenting on Mr. Spitzglass's paper, he would say that the contour of the impact nozzles used in the tests was unsuitable for low-pressure work, as the effect of viscosity, which was most marked at low flows, altered the shape of the stream lines, and hence the distribution of velocity across the section. A nozzle contour which was suitable for Mr. De Baufre's purpose was entirely unsuitable for that of Mr. Spitzglass, where it was essential to work at values of p_2/p_1 which were very nearly unity.

The proposal to use pressure holes further downstream rather than the vena contracta for flow-measurement purposes was, according to Mr. Hodgson's tests, suitable only for the most approximate measurements (unless the orifice had been calibrated in its own pipe line) as variations in the roughness and—in the case of large orifice ratios—the diameter of the pipe caused very considerable variations in the flow coefficient.

It was unsatisfactory to use circular orifices for area ratios greater than 50 per cent, as small errors in centering or in the diameter of the pipe upstream or downstream of the orifice caused considerable errors in the measurement.

For many reasons the most reliable position for the pressure holes was in the plane of the orifice as he had shown in his paper above referred to. It was a matter for regret that Mr. Spitzglass had determined no pressures at these particular points.

Author's Closure

The author, in closing the discussion, said that in regard to Mr. Hogg's question as to whether the coefficient 0.61 for the 10 per cent orifice in a 12-in. pipe was applicable for water and steam as well as for air, the dimensional analysis given in the Fluid Meter Report showed that the values of the coefficient depended on the kinematic viscosity of the fluid, but from all experimental data available water, steam and the common gases showed no difference in the coefficient of the orifice.

As to adopting a distance of one-half diameter for the low-pressure connection of the orifice, he would say that this method had been used by many experimenters, but there was no advantage in adopting it for general practice. In a high-ratio orifice it was very important to place the connection at the proper point and it was best to adhere to this practice. If at any time the orifice was to be changed it would not be necessary to change the connection, as the difference in the factor could be easily obtained from the curves in the paper.

Mr. Hogg had asked whether an equation could be derived to determine the effect of pipe size upon the coefficient of the orifice from the relation of the mean hydraulic radius as pertaining to the friction drop of pressure. The dimensional equation referred to was supposed to correlate the results of tests so that the data of one size of pipe would apply to other sizes by following the law of dynamical similarity in the construction of the orifices.

Mr. Hogg had suggested that an intermediate coefficient be determined by locating the high-pressure tap at the point of restoration and the low-pressure tap at the vena contracta. This was a very good suggestion and to take care of it a modification of Fig. 6 had been prepared for inclusion in Transactions.

The suggestions made by A. F. Spitzglass were a slight addition to the work he had done in preparing the results of the paper.

In reply to Mr. Hendrickson's inquiry, he would state that the coefficient of venturi tube did vary with the velocity of the flow similar to the variation shown on the impact-tube curves. This variation was due to the effect of friction on the approach part of the venturi tube or nozzle. Since the coefficient of friction was generally increased at low velocity, there was a corresponding decrease in the coefficient of discharge, because the additional friction drop increased the relative differential pressure.

As to whether the roughness of the pipe affected the coefficient, he would say that from his experience the nature of the surface was not noticeable except in very high-ratio orifices. For that reason he preferred not to use orifices over the 70 per cent ratio of squares, in which the effect of the surface became noticeable.

If Mr. Dawley would examine Fig. 3 carefully he would see that the first two turns were really long-radius bends and of a size considerably larger than the approach of the flow nozzle. The air flow through any of the pipes lost practically all its velocity when entering the second manifold, which was 14 in. in diameter. The entrance to the third manifold was a long-radius bend of the same 14-in. size. On the top of this manifold each riser was over 6 ft. long and the diameter of the riser was about half the diameter of the manifold and double the diameter of the flow nozzle. With this construction of approach there should be no disturbance or eddies in the flow stream.

Mr. Dawley's suggestion to explore the whole area of the nozzle was carried out during the test. It was found that in case of the 4-in. nozzle the impact pressure did not vary at all until the impact tube was placed $^1/_4$ in. from the circumference of the nozzle. At that point it varied about 1 per cent of the total impact, and when the impact tube was placed so that its edge was in line with the edge of the nozzle, the reduction of the impact pressure was only 3 per cent of the total. This variation was the same in either direction of the nozzle, whether in line or across the turn of the flow at the bottom of the riser.

Mr. Bailey had objected to the method used in the paper to plot the results of the test on the basis of diameter square instead of diameter ratio; which he said was the basis used in Mr. Judd's paper and in others published on the subject. Referring to Figs. 18 and 20 of Mr. Judd's paper, it would be noted that the coefficient of discharge and the factor of correction for velocity of approach were plotted on the basis of the ratio of orifice area to pipe area, and not on the ratio of orifice diameter to pipe diameter. If Mr. Judd chose to call a $2^1/_2$-in. orifice in a 5-in. pipe a 50 per cent orifice, while the results obtained with this orifice were plotted on the 25 per cent line in his main curves, it did not entail any difficulty to compare the author's results with his when he chose to call it a 25 per cent orifice, inasmuch as it really amounted to that figure in the actual comparison of results.

With reference to higher-ratio orifices, the tests had not been limited to 70 per cent, but the results obtained for higher ratios had indicated that extreme accuracy was required in centering the orifice plate and in measuring the pipe diameter. Higher ratios were being investigated at present and the results would be reported later.

Mr. Hodgson's objection to the contour of the impact nozzle used did not apply to this case, because in the author's tests the nozzle was only a means of conveying a stream of fluid and measuring the velocity pressure with an impact tube faced against the stream. The preliminary tests referred to in the paper were made with a nozzle tube, similar to the one shown in Fig. 1 of the paper presented by Sanford A. Moss to the Society in December, 1916 In the final tests the design adopted by Mr. De Baufre was used to see whether the change in design made any difference. In both cases the same velocity pressure was obtained throughout the full area of the nozzle. There was only a change of 3 per cent in the velocity head, which would mean approximately 1.5 per cent velocity at the very circumference of the jet. This proved conclusively that the form of rounding the nozzle was immaterial when used in connection with an impact tube for obtaining the velocity pressure. The use of pressure taps at the point of restoration was recommended because the curve of the coefficient was much flatter at that point in the case of the high-ratio orifices.

Mr. Hodgson did not recommend the use of orifices of over 50 per cent ratio, for the reason that small errors in centering or in the diameter of the pipe would cause considerable error in the measurement. With the method of centering shown in the paper and the correct measurement of the diameter of the pipe, the results appeared to be equally reliable up to an orifice ratio of 70 per cent. As earlier stated, higher ratios were being investigated at present and the results would be reported later.

Mr. Hodgson regretted that readings were not taken of the pressures in the plane of the orifice. This was not necessary, as by extending the numerous points in the first diameter length toward

(Continued on page 399)

[8] Eggington House, Bedfordshire, England.

Steel-Car Construction at the Angus Shops of the Canadian Pacific Railway, Montreal

By H. R. Naylor,[1] Montreal, Canada

In 1909 the Canadian Pacific Railway, to meet the increasing severity of modern traffic requirements, originated a box car having its entire frame built of steel. The production of such equipment in quantity necessitated the erection of an additional shop for the fabrication of the steelwork, and the structure built embodied in its arrangement many novel features for the rapid handling of material to and from the machines and also during the various stages of assembly.

The present paper describes this shop very completely, giving particulars regarding its layout, crane facilities, machine equipment, etc. The various machining operations and the jig method of car assembly, first put into practice at the Angus shops, are presented in detail, and the methods used in the final erection and finishing of cars are dealt with at some length.

IN REVIEWING the improvements that have been effected in railway engineering in recent years, reference is usually made to the heavier and more powerful locomotives employed, grade elimination, heavier rails, improved train control, and terminal facilities; but while great advances have been made in all these directions, it is a question whether the relative advance in any one of them has equaled that in car construction.

The locomotive of higher capacity has been built without material change in the shops or their equipment, grades are removed today in practically the same manner as when the lines were originally built, and the same remarks hold good in regard to rails, train control, and terminal facilities, but in car construction the situation is substantially different. To particularize, a comparison of the modern 60-ton steel-frame box car with the 30-ton wood-frame box car commonly built fifteen years ago brings out two points: the complete change in design, and the effect this change in design must have had on the car shops. It is obvious that the facilities for building the wood-frame car would be quite inadequate for the steel car and must have created new problems with which the car builder had to contend; and it is the author's intention to deal with this phase of steel-car construction, especially as the Canadian Pacific Railway was responsible for many of the important developments.

Development of the Steel-Frame Box Car

The gradual increase in locomotive capacity, making possible the hauling of longer and heavier trains, subjected the wooden cars to severe service conditions, which were in turn met by steel underframes and other steel reinforcements; and at each stage of advancement wood framing was gradually replaced by steel, until in 1909 the Canadian Pacific Railway originated a box car having the entire frame built of steel.

Within a period of six years (1909–1914) this road added 30,811 steel-frame box cars to its equipment and others soon adopted the same design, in some cases with slight modifications. After ten years of extensive service these cars had evidently proved their utility, for the United States Railroad Administration in one order alone included no less than 50,000 of this type.

The Angus shops were already well equipped for building passenger and freight cars on an extensive scale, and the output of wood-frame box cars had reached as high as 40 cars per day. This remarkable organization, however, was rendered obsolete to a large extent when the Canadian Pacific Railway introduced the steel-frame box car to meet the increasing severity of modern traffic requirements, necessitating the erection of an additional shop. This shop was designed for building the steelwork of both passenger and freight equipment, and embodied in its arrangement many novel features for the rapid handling of material to and from the machines, and also during the various stages of assembly. At the time of its erection it probably represented the best practice on this continent, being a combination of the good features observed in other shops with the original ideas developed at the time the layout was being planned.

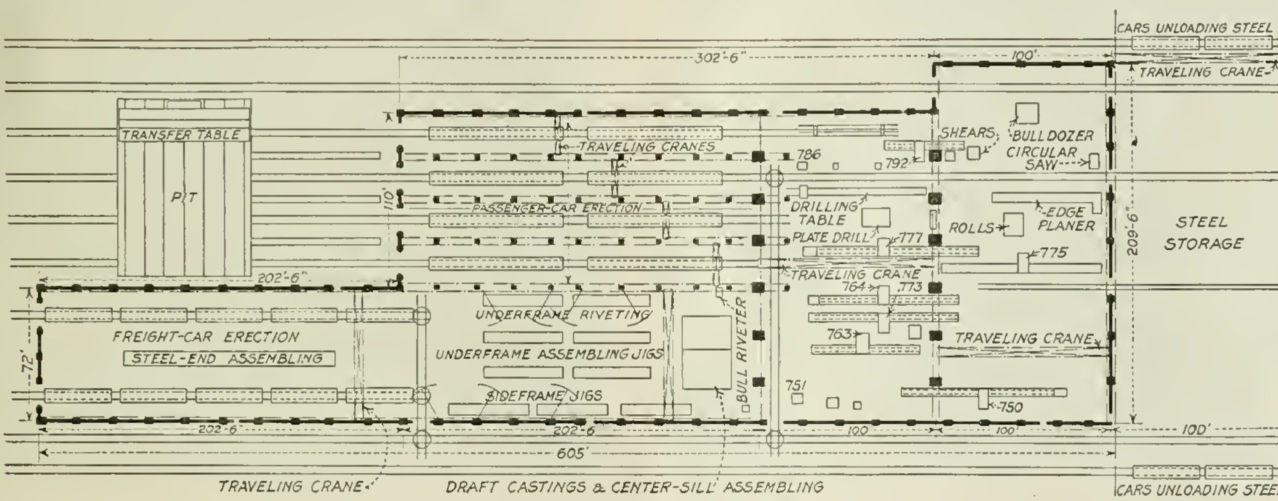

Fig. 1 Plan of Steel-Car Shop of the Canadian Pacific Railway Co. at Angus Shops, Montreal, Canada

The Steel-Car Shop and Its Equipment

The new shop, which is shown in plan in Fig. 1, was located adjoining the wood-freight-car shop, facing a midway upon either side of which were also located the supplementary shops, the midway being served with overhead traveling cranes. It is a steel-frame structure, with steel columns carried on concrete piers, the lower foundation walls being of concrete, 24 in. thick to the ground level and 20 in. thick to a height of $2^3/_4$ ft., above which the walls are of red brick and 16 in. thick. The sash frames are of steel, the total sash area being approximately 40 per cent of the total wall space. The roof is carried on steel trusses with ample skylight area. The floors are of 4-in. concrete with a top surface of $^5/_8$-in. mastic.

There are three main divisions to the shop. The front one facing the midway and occupying the entire front is the machine section consisting of two 100-ft. bays running parallel to the midway, the one adjoining the midway being $209^1/_2$ ft. long, while the inner bay is 182 ft. long. Each bay is served by a 10-ton elec-

[1] Asst. Works Mgr., Angus Car Shops, C. P. Ry.

Contributed by the Railroad Division, and presented at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, of The American Society of Mechanical Engineers. Slightly abridged. All papers are subject to revision.

trically operated crane of the open-latticework type having a span of $96^1/_4$ ft., and a height to base of rail of $28^1/_2$ ft.

The freight-car erecting section is situated in the rear of the machine section, is 72 ft. wide and 405 ft. long, and was originally equipped with one 10-ton traveling crane having a span of $67^1/_2$ ft., and a height to base of rail of 27 ft. An additional crane of similar capacity has since been installed in this section.

Situated also to the rear of the machine shop is the passenger-car erecting section, consisting of four bays having a total width of 110 ft. These four bays with the 72-ft. freight-car bay complete the full width of the back of the machine shop. Each bay of the passenger-car section is provided with a separate 2-ton traveling crane having a span of 24 ft. 10 in. and a height to base of crane rail of 21 ft.

Along the entire front of the shop, between it and the midway, there is ample provision for storing material. This storage yard is 100 ft. wide and is served by a 10-ton crane whose span and height are identical with those in the machine section in anticipation of future shop extension.

Through the freight-car erecting shop, entering from the rear end, are two standard-gage tracks 18 ft. center to center which extend the full length but do not enter the machine shop. Outside the shop and parallel to the south wall a standard-gage track connects with a track on the midway through turntables. This track is used for delivering the car trucks from the truck shop to the final-assembly tracks.

Through each of the passenger-car erecting bays there is a standard gage track leading in from the rear of the shop, also a transfer table for moving the cars during the various stages of completion. Through the center of the material storage yard there is a standard-gage track connecting by turntables with three tracks running into the machine shop.

Crane Facilities. The crane facilities are unique in that the whole area of the shop is traversed by electrically operated traveling cranes so arranged that it is possible to install an unusual number and yet maintain for each crane complete freedom of operation at all times. In this instance the crane arrangement was the deciding factor in the shop layout. It was decided that the machine section of the shop should be independent of the erecting sections in so far as crane service was concerned, and for this reason the crane runways in this section were installed in a direction transverse to those in the erecting shop. This arrangement made it possible to equip the two machine bays with separate cranes, each having a wide range of action with no interference.

The machine layout is arranged with the view of relieving the overhead cranes to the greatest possible extent. This applies particularly to the handling of the larger members, such as center and side sills which are required to pass over two punching machines situated in the different bays. As the first operation is completed the sills are transferred to the second machine by special devices independently of the overhead cranes. On completion of the machining operations the sills are then skidded over to the assembling trestles in the erecting shop without assistance from the overhead cranes.

The two cranes in the freight-car erecting shop, operating on the same runway, are entirely free from machine-shop handling, and as the first one is assigned to the preliminary assembly positions and the second to the final assembly positions, there is no overlapping or interference. The crane facilities in the machine and freight-car erecting shops will be better appreciated if one will endeavor to imagine four cranes on a single runway attempting to handle an equivalent amount of work.

The Machine Equipment. The machine shop is equipped with the following machinery: Four automatic spacing punches, five coping punches, five high-speed punches, two horizontal punches, one 7-ft. 6-in. gate shear, one angle shear, one 36-ft. plate-edge planer, one 30-in. circular saw, one 30-in. metal band saw, one 7-ft. plate roll, one 10-ft. brake, one bulldozer, two special plate-drilling machines, and miscellaneous drill presses, all driven by independent motors.

The arrangement of the machines is such that the material after each operation moves forward in the direction of the erecting shops, backward movement being carefully avoided, thereby reducing material handling to a minimum.

The high-speed punches are belt-driven direct from motor to flywheel, gears being dispensed with. Clutches are of the 6-point type. The heads are equipped with two punches which are controlled by gag levers. These machines are well adapted for punching the smaller plates for which metal templets are made up and into which holes are drilled; by inserting a pin or gage in each successive hole and butting the plate against the pin, the desired spacing is obtained. In certain classes of work the operator can move the material fast enough to catch every hole with the punch running at the rate of 60 strokes per minute.

An unusual plan was followed as regards the installation of machines for heavy punching. The usual practice had been to install a small number of high-capacity machines for the punching and slotting of the sills, side plates and similar members, necessitating frequent changing of dies and templets, with further limitations in the event of breakdowns. It was therefore decided to overcome these handicaps by installing four automatic spacing punches of moderate capacity to obviate the expense and delay of die changing and double handling, and as the five additional coping punches are duplicates of those used in the automatic spacing tables, replacement can be made with but short delay should they become disabled.

Machining Operations on the Car Steelwork

The machines are served by narrow-gage service tracks running from the material storage yard, special care being taken to unload the material close to the track by which it will enter the shop. The progress of material through the machine shop is as follows: Center sills and side-sill channels are loaded by overhead crane and brought into the shop on service lorries and deposited on trestles opposite the traveler at rear of center- and side-sill web spacing punch No. 775. Two air-operated traversing jacks lift the sills in pairs and place them on the traveler rollers ready to pass through the machine. On the far side of this punch, as shown in Fig. 2, is an elevated runway carrying the traveler head which grips the sills with its projecting jaws and automatically spaces the punching. Along the traveler runway steel templets with projecting pins engage a trip lever suspended on the head of the traveler, close the electric circuit, arrest the travel of the head, and close the circuit of the punch control; the punch then completes the operation. After passing through this machine the sills are released from the jaws of the traveler, lifted by jib cranes as shown in Fig. 2, and deposited back to back on the rollers of sill-flange-spacing punch No. 777, which are placed directly opposite the delivery end of the web punch. On completion of the first operation the sills are disengaged from the head clamp and pushed back over the rollers to the starting point, where they are again turned over by a special device attached to the jib cranes and passed through the machine for the second operation on the opposite flanges. The sills are then lifted by the traveling crane of the inner section of the machine shop and placed on the rollers of coping punch No. 763 directly opposite, where draft-key and lever slots are punched, completing the operations on the sills.

The center-sill and body-bolster cover plates and similar plates are punched on spacing punch No. 750. The side plates are punched on automatic spacing punch No. 764 in a similar manner to the sills, passing through for the first and second operations in pairs.

In all of these operations the passage through the machines is rapid and the accuracy of the spacing mechanism is such that the punching error is slight and far less than it would be were each hole marked off and punched independently.

There are certain parts which cannot be handled satisfactorily on the spacing punches, yet the punching must be equally as accurate or otherwise much of the benefit obtained from the spacing punches is lost when the parts are assembled. The machining of the ends of the side posts and braces is an example of this kind. In this case special combination dies are used to shear the ends to shape and punch the group of holes in one operation.

The bolster cover plates and diaphragms are machined in a similar manner, the cover plates being passed over the spacing punch and the diaphragm flanges punched on one of the coping punches equipped with special dies for punching the flange holes in one operation. During these operations the machine is relieved

Fig. 2 Center- and Side-Sill Web Spacing Punch

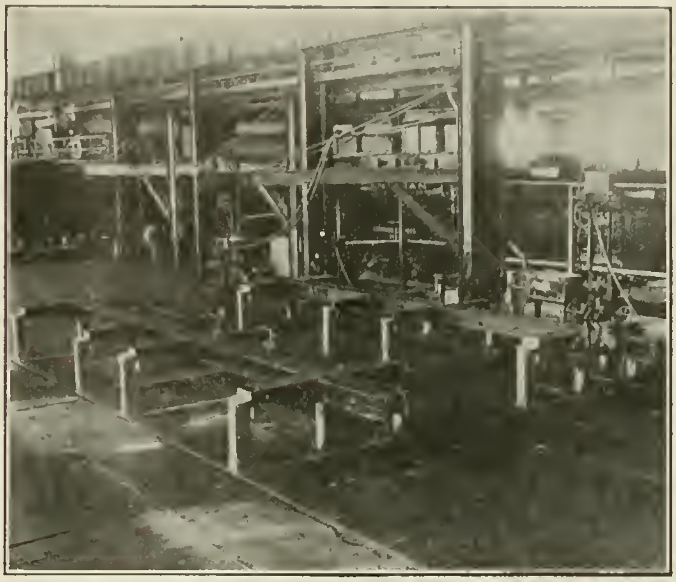

Fig. 3 Jigs Used in Assembling Underframes

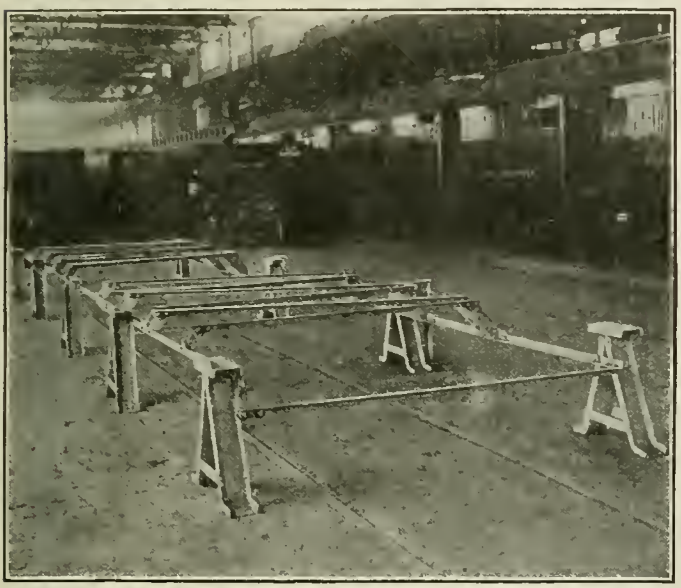

Fig. 4 Jig Used in Assembling Side Frames

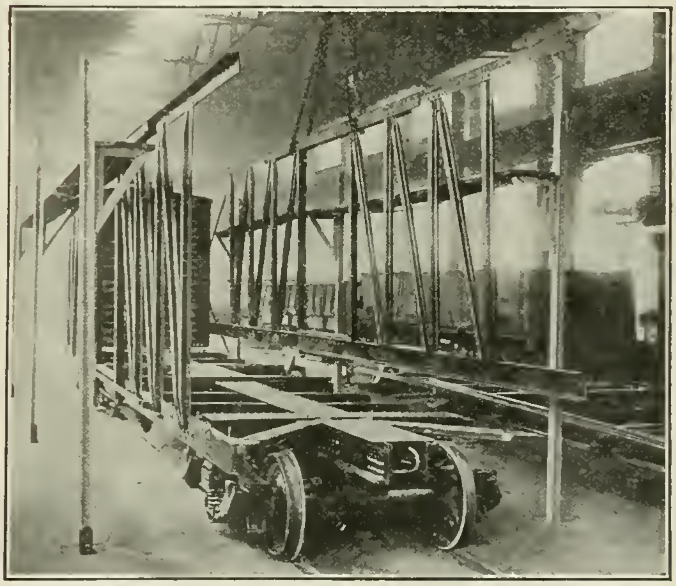

Fig. 5 Placing the Side Frames in Position

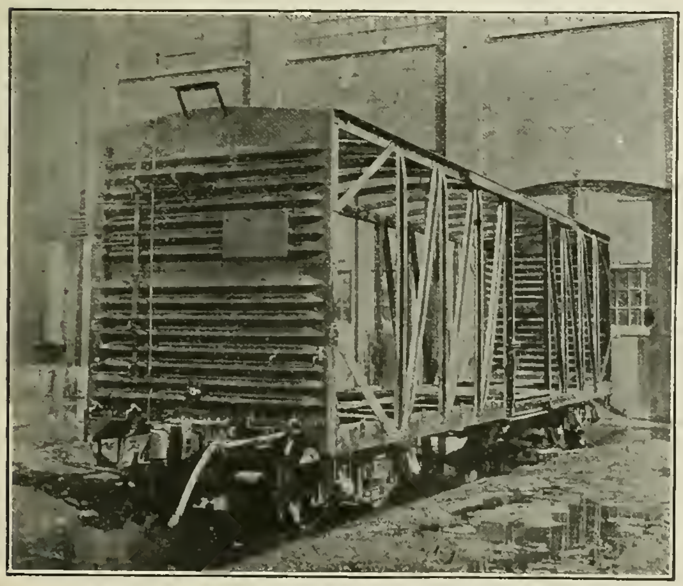

Fig. 6 Car with Steelwork Completed and Ready for Finishing

Fig. 7 Car Completed and Ready for Service

of excessive load by varying the length of the punches, resulting in the holes being punched consecutively.

The usual practice for freight-car work is to punch rivet holes to a diameter not exceeding that of the rivet, and, when the parts are bolted together, to ream the holes to a size not exceeding that of the rivet by more than $^1/_{16}$ in.

The Jig Method of Car-Frame Assembly

The erecting of steel-frame box cars by the jig method was originated at the Angus shops. By this method the underframe, side frames, and end frames are assembled on jigs as complete units ready for the final assembly of the car. The jigs consist of stands or cradles by means of which the various members are accurately placed and held in proper relation to each other until they are riveted together. The advantages of this method are manifold. As each member lies flat in the jig, the drawing together of the parts is reduced to a minimum, wedge bolts being used extensively for this purpose as they can be rapidly applied. A complete unit being assembled in one operation, the possibility of accumulative error is avoided. The jigs dispense entirely with checking for squareness, alignment, and location of connection holes, thereby simplifying the final assembly to a considerable extent. Before any of the parts are assembled, all concealed surfaces are painted to prevent corrosion.

The center-sill channels after passing through slot-punching machine No. 763 are skidded from the idler rollers to trestles just inside the erecting shop, where the draft castings are temporarily bolted on and the holes reamed ready for riveting. An electric hoist operating on a runway below and clear of the overhead cranes, swings the sills into position and the draft castings are riveted on by a compression riveter. The individual sills are then moved across to a position on the left where the two center sills are assembled and riveted with bolster center castings and separators in position. The sills are placed on stands on which are four fixed pins corresponding to four rivet holes in the sills at the center line of the bolsters. By placing the sills flange down on these pins perfect alignment of the two sills is assured, which simplifies the application of cover plates later on. The draft gear is also applied in this position.

The next step is the assembling of the underframes, and as this is a lengthy operation, four positions are assigned for the purpose as indicated in Fig. 1. These jigs, as shown in Fig. 3, consist of four steel cradles located at bolster and cross-bearer centers, and so arranged that each member of the underframe is held in proper alignment and at centers that will coincide exactly with connections on the side frames. The bottom cover plates of the bolster and cross-bearers are first placed on centering pins; the overhead crane then places the center sills in position, to which are attached the bolster and cross-bearer diaphragms with their cover plates and center-sill cover plate complete, after which the assembly is bolted together and the holes reamed ready for riveting.

The underframes are then swung over by the overhead crane to the riveting jigs on the right, which are constructed similar to those used for assembling, thereby maintaining the proper alignment. Each riveting position is equipped with two 50-ton compression riveters suspended from swinging jib cranes, the posts of which are in line with columns to the right. The crane jibs are 21 ft. in length with runways for air hoists, the suspension mechanism being so arranged that the riveters can be tilted to drive the rivets in the inclined bottom flanges of the bolster and cross-bearers, which otherwise would have to be driven by an air hammer. The compression riveters were specially designed on the scissors principle, with a thin nose to permit of the top and bottom rows of rivets being driven without turning the underframe over in order to complete the operation.

The side frames, consisting of the side sill, side-plate, posts, braces, door posts, and track, are assembled as a unit on a jig frame situated abreast of the underframe jigs. This jig, as shown in Fig. 4, consists of channel-iron stands, the four corner ones of which are capped with short sections of channel iron in which are holes for locating exactly the side sills and plates. The stands on either side are tied together with angle bars which carry additional cross-bars upon which the various members of the side frames are placed in proper relation to each other. In this position the side frame is temporarily bolted, reamed, and riveted ready for the final assembly position.

Originally the end frames were assembled on jigs similar to those used for the side frames, but in recent years the end-post construction has been replaced by corrugated-steel ends. These steel ends and the end sills are assembled on trestles located between the final assembling tracks, and when temporarily bolted together they are skidded to the second and third positions where they are then reamed and riveted. In the fourth position the end ladders, roof-frame brackets, and other parts are applied, the ends as completed being then placed opposite the final assembling position.

Erecting and Finishing the Cars

As the trucks are assembled and painted, they are delivered from the truck shop and enter the erecting shop by the side door immediately ahead of the underframe and side-frame jigs, where they are turned on a turntable and placed in position on the assembling track. The underframe completed in the riveting jig is then lifted by the overhead crane and placed on the trucks, the slings are released, and a steel end is next placed in position and bolted on the end farthest away from the side-frame jigs; the side frames are then placed in position as in Fig. 5, and finally the second end, along with the center and side-sill cross-ties. The brake-cylinder reservoir and piping are also applied at this time.

The car is then moved by car haul to the second position where the assembled members and the roof framing are riveted in place. In the third position the safety appliances, brake rigging, couplers, uncoupling rods, etc., are applied, the remainder of the riveting completed, and the entire frame as shown in Fig. 6 is then sprayed with the priming coat of paint, when the car is ready for finishing.

The steel frames are switched each day to the wood freight-car shop where the decking, sheathing, roofing, and doors are applied and the painting operations are completed. The decking is of $1^3/_4$-in. red pine and the sheathing of $1^1/_2$ in. Douglas fir, both having tongued-and-grooved joints. High-grade lumber free from knots, checks, or cracks is selected for this purpose and is then kiln dried, the moisture content being carefully limited in order to prevent the possibility of further shrinkage later on; the only objection of any importance raised against the steel-frame box car, as compared with other box cars, having been one arising from improper drying of the sheathing.

Before leaving the planing mill the sheathing, roofing, and running boards receive their priming coat of paint in a painting machine recently developed at the Angus shops and which differs from those in use elsewhere. The boards on leaving the matcher pass automatically through this machine where they are sprayed by a series of nozzles which can be set in any desired position according to the surfaces required to be painted. The paint is drawn up through suction pipes from the bottom of the box by means of air jets blowing across the nozzles, and as ejected it is atomized by the air and blown on to the boards in the form of a fine spray. The amount of paint to be applied is controlled by air valves or by regulating the speed at which the boards pass through the machine. No brushing or wiping is necessary. The boards on leaving the machine are piled on trailer trucks and distributed by tractors to the shops when dry. These machines will paint at the rate of 200 running feet per minute, which is about as fast as the boards can be conveniently piled for drying.

The first operation in the wood freight-car shop is to apply the decking, the joints of which are previously coated with a thick paint compound, as are also the ends of the boards making contact with the bottom boards of the side sheathing previously applied.

The side sheathing which has already received the priming coat of paint is next applied, and to insure that the sides of the car will be watertight, the joints are coated with paint compound, after which they are wedged down into position and bolted to the framing. The end lining is then applied in a similar manner but vertically. In the succeeding operation the roof is applied, the boards and metal sheets of which have previously been primed.

After the doors are hung in place and the remainder of the safety appliances have been installed, the car is given two additional coats of paint and stenciled, when it is complete and ready for service, as shown in Fig. 7.

Recent Developments in Balancing Machines

By CARL RICHARD SODERBERG,[1] EAST PITTSBURGH, PA.

The balancing of rotating machinery is still far from being an exact science, although it has received a great deal of attention during recent years. The balancing of small high-speed motors for domestic use has been neglected to a great extent because satisfactory balancing equipment has not been available. The necessity for balancing this type of rotating apparatus is continually growing with the increase in speed and capacity and the customers' demands for a lasting product. The present paper is a brief description of efforts made to solve this problem and of a balancing machine finally developed that eliminated the difficulties and made it possible to manufacture quietly running motors.

SEVERAL fundamental difficulties, in addition to those encountered in balancing rotors of ordinary size, are involved in the problem of balancing small rotors.

a The balancing operation must be performed in a few minutes because the total cost of each unit is so low

b The high speed necessitates a very accurate balance

c The actual values of the centrifugal forces that are produced by a considerable unbalance are so low that it has been found extremely difficult to obtain an indicating device for the vibrating motion.

Because of these difficulties several attempts to produce a balancing machine for small armatures, operating on the usual principles of separating the static and the dynamic unbalance, have failed. It was decided, therefore, at the beginning of the investigation, to follow a plan that would procure complete balancing in one operation, without previous static balance. Arrangements of this type have been used before, but in these the balance is obtained by three weights, two of which cause considerable inconvenience in computing.

It is shown in an appendix to the complete paper that the general state of unbalance can be corrected by two masses, one in each of two transverse planes of the body. This can easily be understood by recalling the fact that any system of forces emanating from a straight line may be counteracted by two forces.

The most common type of balancing machine now on the market consists of a vibrating table so supported on springs and a fulcrum that the table is capable of performing small vibrations around a fixed axis. On this vibrating member are mounted the rotor to be balanced, a "dynamical image" of this rotor, usually consisting of a variable couple, and a driving mechanism for rotating the body and its image. If the fulcrum axis is parallel with the axis of rotation, the unbalanced dynamic couple is eliminated and the static unbalance can be ascertained and corrected. By shifting the fulcrum axis to a position at right angles to the axis of rotation, the remaining couple will be effective and may be determined and corrected. In both instances the vibrating table performs a forced vibration under the influence of the unbalanced forces in the body, and the amplitude of this motion is increased by adjusting the speed of rotation so that resonance occurs. Thus the sensitiveness of the machine is magnified without undue increase of speed. The original dynamic balancing machine, the squirrel-cage machine, devised by Akimoff[2] several years ago, was the first arrangement of this kind. Quite frequently the static balance is performed on parallel ways.

The static-dynamic balancing machine has the following fundamental disadvantages:

a The static balancing generally increases the magnitude of the unbalanced couple because of incorrect longitudinal location of the correction weights. Thus, the amount of balancing weights is greater than necessary

b The number of places in which correction weights are applied is frequently four and cannot be reduced to less than three, while the theoretical minimum is two

c Any error in the static balancing will have a serious effect on the determination of the couple. The effect of residuary static unbalance is frequently magnified on account of the large moment arm. In order to obtain a balancing result with a certain tolerance it is therefore necessary to perform the static balancing with exaggerated accuracy.

With the disadvantages in the existing equipment and the special requirements for the balancing of small rotors, the following demands were made on the new type of machine:

a Balance should be obtained by adding the theoretical minimum of weights to the body; that is, the two theoretical masses necessary for counteracting the system of unbalanced centrifugal forces should be given in the result

b The balancing operation should be performed with uniform accuracy; that is, the effect of one mass should be eliminated while the other mass is determined

c The balancing operation should take short time and be inexpensive, so that it can be applied to quantity production.

Balancing Machine with Movable Fulcrum

Fig. 1 shows schematically an arrangement whereby the general

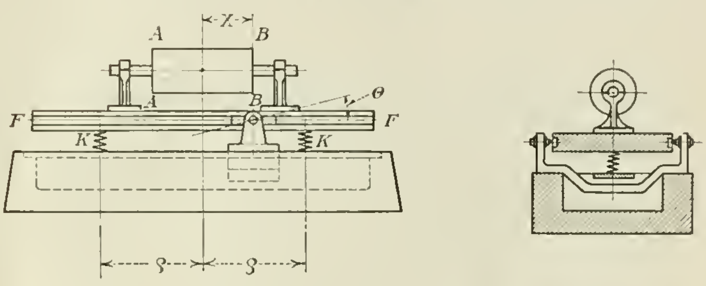

Fig. 1 Schematic Arrangement of Balancing Machine

state of unbalance may be obtained without segregation into static and dynamic unbalance. The body to be balanced is mounted in bearing blocks on a vibrating table supported by two spring members and a movable fulcrum member. This admits of motion around any axis in the plane *F-F* at right angles to the axis of rotation. Assuming that the transverse planes *A-A* and *B-B* have suitable arrangements for the application of correction weights, it is certain, from the above, that any unbalance in the body may be corrected by one weight in each of these planes. By placing the fulcrum axis in one of these planes, say, *B-B*, the theoretical weight in this plane is eliminated as far as its effect upon the motion of the vibrating table is concerned. This will now be produced by the unbalance in the other plane.

If a counterbalancing device for measuring the amount and the angular position of this weight is added to the arrangement, the unbalance may be determined in the same manner as static or dynamic unbalance is determined in the old type of balancing machine. By subsequently placing the fulcrum in the plane *A-A* the effect of the unbalance in this plane is eliminated, and the same procedure may be applied for determining the weight in the plane *B-B*. It is evidently of no importance whether the balancing weights are applied during the operation or not, since the effect upon the vibrating table is reduced in each case to that of one unknown weight. It is also evident that this arrangement meets the requirements.

This arrangement, which has been called a balancing machine with a movable fulcrum, was adopted as the most suitable one for balancing small armatures. There is, however, no indication that its application will be restricted to small rotors.

Features of the First Design

The subsequent design of an operative machine offered a number

[1] Engineer Motor Engrg. Dept., Westinghouse Elec. & Mfg. Co.

[2] Dynamic Balance, by N. W. Akimoff, Trans. A.S.M.E., vol. 38 (1916), p. 367.

Presented at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, of The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y. Abridged. All papers are subject to revision.

of interesting problems. There are two possibilities with reference to the operation of the device:

a Determining the magnitude and the location of the unbalanced masses by means of a counteracting device

b Determining the magnitude of the unbalanced masses by the amplitude of the motion, and the location by "cut and trial" or by "marking" the rotor.

Although these two systems are different, they have no bearing upon the following theories. The first model was built and operated in accordance with the second alternative mainly because unbalance on the type of motors for which the model was built could easily be corrected by inserting wedges into the slots. It seems probable that, in this particular case, no gain could be obtained in speed of operation by applying a counterbalancing device. The following principles relate to either one of these alternatives and will be discussed separately for the sake of clearness.

Speed Variation for Different Locations of the Fulcrum Axis. Since the moment on inertia of the vibrating system varies with the location of the fulcrum axis, it is to be expected that the natural period, and hence the resonance speed, should vary. It has been found, however, that an arrangement can be made in which the restoring element receives a corresponding variation, so that the quotient remains constant. The theoretical explanation is given in a second appendix to the complete paper. Result of this investigation shows that if the two spring members are identical and located symmetrically with reference to the center of gravity of the vibrating bed and at a given distance, the natural period of the system is independent of the fulcrum location. Fig. 2 gives an illustration of the principle for the specific case where the center of gravity of the vibrating system is located in the fulcrum plane.

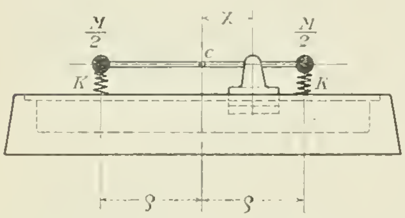

Fig. 2 Special Case with Center of Gravity of Vibrating System in Fulcrum Plane

A constant balancing speed is very essential for efficiency and accuracy. The latter is largely dependent on the degree of resonance, and a slight error in the speed may distort the result altogether. The type of indicating device that was adopted served to increase the importance of constant speed.

Naturally the principle does not admit a variety of armatures to be balanced on the same set-up. As far as small rotors are concerned, they are manufactured in large lots, thus making it necessary to have a balancing machine for each type. When frequent changes have to be made, a vibrating table may easily be supplied for each type of armature.

Indicating Device. The indicating device proved to be a stumbling block. Attempts to use the ordinary type of dial gage indicators failed altogether. There was always the possibility of using the conventional mirror and light beam, but it was not considered practical in production routine. A vibrating reed was finally applied with success. Spring steel 0.125 in. by 0.006 in. is used on the present model and the amplitude of the reed is a tolerably good measure of the angular deflection of the vibrating bed. The resonance of a reed of this type is considerably sharper than the resonance of the vibrating table itself. This is a decided advantage, because erroneous readings are eliminated. It necessitates, however, a constant speed of the driving arrangement.

Driving Mechanism. The requirements for constant speed magnified the importance of the driving motor. Several attempts were made with a small motor mounted on the vibrating table, but without success. The kinetic energy of the rotating masses must be sufficient to resist variation in the friction load. As long as the driving motor is mounted on the vibrating table, its weight must be restricted in order that the vibrating mass may not be too great. In the arrangement used at present the rotor is being driven by a fairly large a.c. motor mounted on the solid foundations. The driving belt consists of a silk ribbon. This arrangement has proved to be satisfactory. The disturbance of the belt is not sufficient to influence the motion of the vibrating bed.

Predetermination of Sensitiveness. The problem of predetermining the amplitude for a given unbalance necessitates a closer study of the factors that limit the motion at resonance, and a better knowledge of the internal friction of springs is therefore of extreme importance. Little work has been done along this line, however, and there are no reliable methods available for the predetermination of the internal friction in springs. It is generally assumed that the damping of a spring is a linear function of the speed, and this appears to be fairly true for small motions. A variation of the spring characteristic for different degrees of compression will also limit the amplitude at resonance, although in a manner different from that of internal friction. If this variation is large it may seriously impair the resonance. The requirements of springs for balancing machines are therefore:

a Straight-line characteristics

b Low internal friction.

The relation of the amplitude, that is, the angular deflection of the vibrating bed, to the unbalanced moment is explained in a third appendix to the complete paper. It is shown that the angular deflection is directly proportional to the unbalanced moment with regard to the fulcrum axis and inversely proportional to the damping factor. This is true for perfect resonance and for the assumption that the damping is proportional to the first power of the speed. It has also been found in this investigation that the major part of the damping effects occurs in the springs themselves. The total damping is therefore a function of the location of the fulcrum axis. The minimum of damping occurs at the central location of the fulcrum. Therefore the amplitude is not a direct measure of the unbalanced moment; it is always possible, however, to place the rotor in such a manner that the readings have the same value for the two planes in which the unbalance is corrected, because the variation of the damping factor is symmetrical with reference to the central location of the fulcrum.

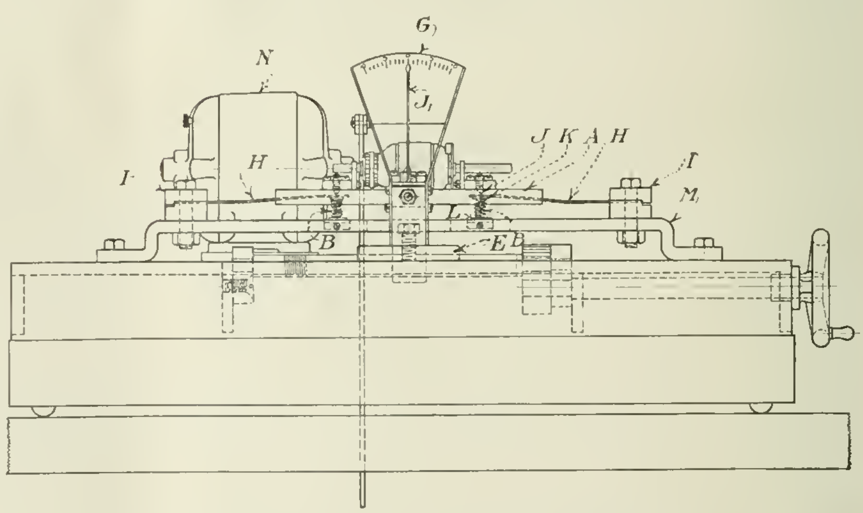

Fig. 3 Side View of Balancing Machine with Movable Fulcrum

There is, however, another factor of importance in this connection. It is theoretically true that if the springs have straight-line characteristics and a sufficiently low internal friction, a small disturbance (unbalance) will produce a considerable amplitude. If the disturbance is small, however, the time required by the vibrating system to absorb sufficient kinetic energy to attain its maximum amplitude will increase. This introduces another element into the problem, namely, the proportion between the moment of inertia of the vibrating system and the magnitude of the disturbance. Common sense tells us that there is a certain limit to the moment of inertia of the vibrating system for each amount of unbalance to be measured, but no attempt has previously been made to establish actual values. In the author's

opinion, the time required for the balancing machine to "pick up" and the amount of internal friction are the two elements that enter into the question of sensitiveness. It is shown in a fourth appendix to the complete paper that this time element is largely dependent on the quantity P/I; that is, the proportion between the unbalanced moment and the moment of inertia of the vibrating system. The minimum value of P/I will thus be a logical measure of the sensitiveness of the balancing machine. Below are given minimum values of P/I that were obtained in the model with a movable fulcrum and three other balancing machines of the usual type.

	Value of $(P/I)_{min}$
1 Model with movable fulcrum	15×10^{-6}
2 125–500-lb. balancing machine	0.6×10^{-6}
3 500–3000-lb. balancing machine	0.45×10^{-6}
4 3000–10,000-lb. balancing machine	0.4×10^{-6}

These values were obtained by experiments on the balancing machines. They are influenced, therefore, by the following factors:

a The nature of the indicating device
b The damping factor
c The actual value of the moment of inertia of the vibrating system with regard to the axis of oscillation.

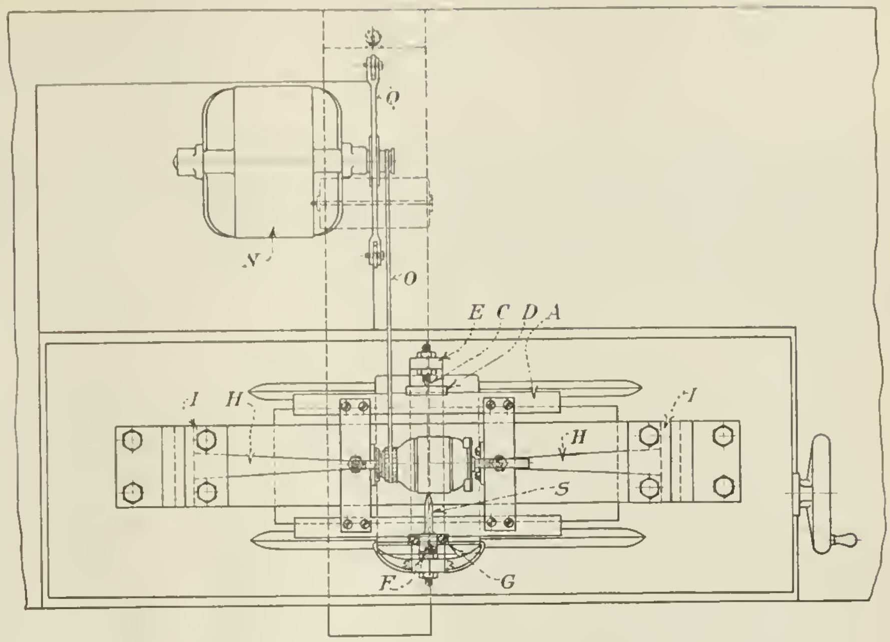

Fig. 5 Plan View of Balancing Machine with Movable Fulcrum

The model with a movable fulcrum has an indicating device which records the angular deflection of the vibrating bed so that only the sensitiveness of this device (amplitude per radian) enters into the expression P/I. The other machines, however, are equipped with dial gage indicators so that in the sensitiveness of the indicator is also included its distance from the axis of oscillation. This distance is usually made as large as possible. The larger machines therefore have the advantage of a more sensitive indicator. The dial gage indicators on these machines are all of the same type. A total amplitude of 2 deg. (0.002 in. linear motion) is considered the minimum detectable motion.

The damping factor and the moment of inertia are variable in the model with a movable fulcrum. Therefore, the value of P/I refers to the central location of the fulcrum.

The balancing machines in cases 2, 3, and 4 are of the same type. They show a tolerable consistency in the minimum value of P/I with a slight increase for the lower capacities. The model with a movable fulcrum has a capacity of an entirely different order and the value of P/I is increased correspondingly. This illustrates the difficulty in obtaining an accurate balance of small rotors. In order to keep the minimum unbalance sufficiently low it is necessary to have the moment of inertia of the vibrating system exceedingly small.

It would be highly desirable if the limiting values of P/I could be learned when a balancing machine is purchased. The buyer would then be able to tell if the lower limit is consistent with the accuracy of balancing that he wishes to obtain on the smallest rotor to be balanced. At the present time balancing machines are rated with reference to the maximum and minimum weights of rotors to be balanced. The upper limit may be necessary from the point of view of stresses in the mechanical structure. The lower limit does not, however, give reliable information with regard to the accuracy of balancing.

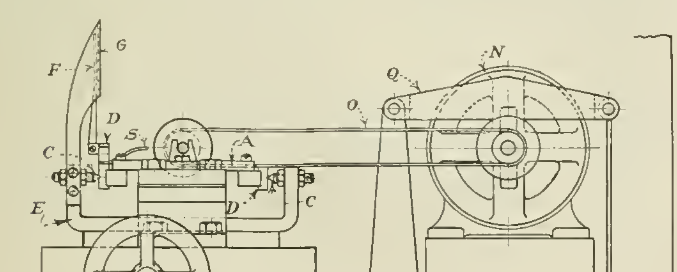

Fig. 4 End View of Balancing Machine with Movable Fulcrum

Description of First Model

Figs. 3, 4, and 5 show a balancing machine with movable fulcrum adapted to balance an electric armature weighing about 9½ oz. Fig. 3 is a side view, Fig. 4 an end view, and Fig. 5 a plan view. The machine is shown mounted on a working bench with a foot-operated starting and braking arrangement of the driving motor.

The vibrating bed *A* is supported by the coil springs *B* and the pivots *C*. These pivots engage in centers on the sliding blocks *D* so that by moving the carriage *E* the axis of oscillation is moved relatively to the armature. The location of the pivots with reference to the armature is indicated by the pointer *S*. One of the sliding blocks carries the vibrating reed *F*, which vibrates across the graduation on the scale *G* attached to the carriage *E*. The indications of the reed are therefore proportional to the angular deflection of the vibrating bed.

The bed is prevented from moving in the horizontal plane by the flat springs *H*, clamped in the blocks *I*. These flat springs press against the knife edges *J* which have center pins engaging in centers on the caps *K* of the coil springs. The flat springs have slots to fit these pins. The slots are machined so that there is practically no clearance in the lateral direction but a considerable clearance in the longitudinal.

The coil springs are supported on the longitudinal member *M* by the adjustable seats *L*. Thus the length of the springs may be adjusted so that the entire weight of the vibrating system is carried by the springs. In this case the pivots carry no other load than that of the inertia forces. The carriage *E* moves underneath the spring-supporting member *M*. This admits of moving the fulcrum member past the springs if desired.

The driving motor *N* is a single-phase induction motor starting as a repulsion motor. The load is very small so that it runs at

(Continued on page 383)

The Development of Industrial Safety Codes

By M. G. Lloyd,[1] Washington, D. C.

After giving statistics showing the need for accident-prevention work from both the humanitarian and the economic viewpoint, this paper shows the value of state inspections and national codes. It then presents a brief history of the American Engineering Standards Committee's activity in this field and of the Safety Code Correlating Committee. The paper closes with an outline of the manner in which safety codes are now formulated.

The past dozen years have shown a growing interest in accident prevention and a rapid development of activities for the elimination of casualties. The extension of compulsory compensation laws, which now cover all but the District of Columbia and five states of the Union, has given accident prevention in industry an economic status which it did not previously possess. Prior to this era claims for damages by employees could be resisted in the courts by employers and the defense of contributory negligence acted to eliminate many such claims. Under the present compensation laws, however, the payment of such claims has become more certain and definite in amount. Compensation insurance is very general and its cost is in most cases dependent upon the accident experience of the policy holder. There is consequently a very definite economic incentive for the reduction of industrial accidents.

In the fiscal year ended June 30, 1920, the Federal Government spent about $1,350,000 for accident prevention and sanitation work in industry, representing an expenditure of about 1.3 cents per capita. The part of this amount used for accident-prevention work in the manufacturing industries represents an expenditure of about 8 mills per thousand dollars of value of manufactured products. In the case of mineral products the disbursement is about 9.5 cents per thousand dollars of value of products.

Most of the states have a department of labor or industrial commission administering compensation, and many of them have authorized such commissions o undertake work for the prevention of accidents or else provide an independent state factory inspector. In 1919 the various states spent for accident-prevention work $2,723,000, or about twice as much as the Federal Government spent for safety and related purposes.

No reliable estimate can be made of the amount of money expended each year by the industries themselves in improving the physical conditions of their plants and in other activities related to accident prevention. In addition to such expense they must also meet compensation costs, attorneys' fees, and other expenses occasioned by accidents. The expenses of many individual corporations annually in connection with accidents and safety work mount into six figures, and the total for all industries must run into many millions. The railroads of the country alone paid out in 1917 over $33,000,000 chargeable to accidental injuries. There were in that year 10,087 fatalities and 210,729 cases of injuries. The average cost was thus over $150 per accident.

This immense waste of human resources has both a humanitarian and an economic aspect. The economic waste involved is of great importance to industry. So far as it depends upon physical conditions of plant equipment and operation it can be largely eliminated by compliance with the principles of accident prevention which it is the function of safety codes to apply in detail to specific industries or operations.

State Inspection

The principal activity by which the state officials can reduce accidents is the inspection of factories and other work places and insistence that they shall be so constructed and operated as to provide for the safety and health of employees. In making such inspections it is necessary that the inspector should have some standard of comparison by which to judge of the conditions which he encounters. Only by having such a standard of reference is it possible for different inspectors to treat different cases upon a uniform basis or even for a single inspector to be consistent in his decisions with reference to different industrial plants. Such a standard may exist only in the mind of the inspector and be subject to development and change from day to day. Much more satisfactory results, however, can be obtained by having written standards subject to change only by definite action of the administrative authority and capable of being known to factory managers, manufacturers of machinery, and others concerned with them before installations are made. It is then possible for such persons to plan their installations so as to meet the requirements of the state officials. In that way more complete compliance on a more satisfactory basis is obtained.

It will be apparent that the greatest satisfaction to both inspector and factory manager will result from inspections and the enforcement of regulations when the latter consist of a definite set of written rules which have been given full consideration before adoption and which are applied uniformly by all inspectors within a given jurisdiction and are modified only by definite administrative action after due notice and full consideration. Consequently most of the states which are active in factory-inspection work have definite regulations, and it is the duty of their inspectors to see that such regulations are complied with.

These regulations may take the form of statute laws or of rules promulgated by some administrative authority. Where the regulations are established by statute it is impossible to alter or amend them except by the same legislative process. Where the regulations are promulgated by administrative authority, changes and amendments can be made from time to time as experience or progress in the art makes it advisable to do so, and a system which is more flexible and in general more satisfactory to all parties concerned is obtained.

Whatever legal form the regulations may take, it is desirable that they be as definite as possible, be so drawn up as to be easily understood, be available in printed form for the guidance of all interests concerned, and be given very thorough consideration by all parties and interests before their mandatory adoption.

Such a code of safety rules is valuable not only for mandatory enforcement by administrative authorities and for authorized inspectors, but as a guide to the industry concerned in improving its methods and modifying its previous practices. Many manufacturers are only too glad to make improvements in the physical condition of their plants when the possibility of such improvements is pointed out to them, and many of them are eager to apply any information which will improve the welfare of their employees. The greatest value of the safety code is probably in providing such information as a standard for the guidance of the factory manager, and the author considers its usefulness as a regulation for legal enforcement to be secondary to this.

Advantages of National Codes

Most of the safety codes heretofore adopted and enforced by state boards and commissions have been developed locally and usually with the coöperation of a committee representing local interests. In the preparation of such codes, use is frequently made of standards already adopted by other states or by industrial and engineering associations. In some cases such standards already available are adopted without change, but more often changes of greater or less extent are made for the purpose of improvement or of meeting some real or fancied need caused by local conditions. This is well illustrated by the Boiler Code prepared by The American Society of Mechanical Engineers and the Electrical Safety Code prepared by the Bureau of Standards. If the national codes were generally prepared by processes which would take into consideration local variations and conditions, and which guaranteed the full consideration of the viewpoint of every interest involved and freedom from domination by any one interest, particularly such as might

[1] Chief of Safety Section, U. S. Bureau of Standards; vice-president. American Society of Safety Engineers.

Presented at a joint session of the American Society of Safety Engineers and the A.S.M.E. Safety Codes Committee at the Annual Meeting, New York, December 4 to 7, 1922, of The American Society of Mechanical Engineers. Slightly abridged. All papers are subject to revision.

be of a commercial character, it would seem advantageous to adopt such national codes without the introduction of local variations. This would give the advantage of uniformity in requirements in different jurisdictions. The manufacturers of equipment could then supply a single line for use in all states, thus reducing production costs, and the work of the contractor and inspector would be simplified. It would also be easier for the insurance companies to harmonize their own requirements with those legally enforced by the state authorities. As it has been in the past, and is now, the requirements of state inspectors and insurance inspectors are frequently different, resulting in confusion and friction, and a disinclination upon the part of the factory manager to comply with either. If these standards were made uniform, and all concerned with safety agreed upon the physical conditions for attaining it, there would be greater readiness to follow such standards in practical shopwork.

To obtain national codes of this character it is necessary that their preparation be accomplished by the widest and most thorough consideration of those familiar with the particular problems of the industry concerned and that full weight be given to the viewpoints of all interests involved.

Realizing the importance of safety codes prepared upon a national basis, and as the result of the contacts made by its previous work in this field and the demands for more extensive work of the same character, the Bureau of Standards called a preliminary conference on this subject in Washington in January, 1919, and a second conference in December of the same year. At these conferences the subject was fully discussed, the need for national codes generally recognized, and the best method for preparing them given full consideration. It was finally agreed that the scheme of procedure in establishing national standards which had been inaugurated by the American Engineering Standards Committee would be the most satisfactory to utilize in the preparation of safety codes, and it was finally voted by a large majority that they should be prepared under the auspices of this committee. It was realized, however, that in order for this plan to be widely acceptable it would be necessary to enlarge the scope and membership of the American Engineering Standards Committee, and this was done as a direct result of these conferences.

Safety Code Correlating Committee

As a result of the 1919 conferences a National Safety Code Committee was formed which is now known as the Safety Code Correlating Committee. It acts as an advisory body to the American Engineering Standards Committee in all matters relating to safety codes, its membership being such as to give it more direct contact with the desires and needs of those most intimately concerned with safety matters. Its present membership includes representatives of the following:

- American Gas Association
- The American Society of Mechanical Engineers
- American Society of Safety Engineers
- Association of Governmental Labor Officials
- International Association of Industrial Accident Boards and Commissions
- National Association of Mutual Casualty Companies
- National Bureau of Casualty and Surety Underwriters
- National Electric Light Association
- National Fire Protection Association
- National Industrial Conference Board
- National Safety Council
- U. S. Bureau of Labor Statistics
- U. S. Bureau of Mines
- U. S. Bureau of Standards

The first report of this Committee in 1920 included a list of thirty-seven codes which were considered of the most immediate importance and for which sponsor bodies were recommended. Since that time it has made additional recommendations from time to time and the Engineering Standards Committee has referred to it questions concerning safety codes which required investigation before decision.

The members of the Safety Code Correlating Committee are frequently designated by the chairman of the Engineering Standards Committee to serve upon special committees which investigate the make-up of Sectional Committees for safety codes or advise the Engineering Standards Committee as to the suitability of approval of standards in this field which have been submitted to it. The Committee thus functions in general to advise the Engineering Standards Committee and keep it informed when necessary on matters relating to the field of safety codes.

The Preparation of Safety Codes

When, after recommendation from the Safety Code Correlating Committee, the American Engineering Standards Committee recognizes the need for the development of a particular safety code, it designates one or more sponsors to manage the formulation of such a standard and the sponsor body organizes a Sectional Committee containing representatives of all organizations which are considered to have an interest in the development of this particular code. Such Sectional Committees usually contain representatives of the following groups of interests:

- Manufacturers of the equipment
- Employers
- Employees
- Regulatory government representatives
- Technical experts
- Casualty-insurance companies

The Sectional Committee must have its make-up approved by the American Engineering Standards Committee as being properly representative and well balanced as to interests which may have different viewpoints. This Sectional Committee may itself carry out the work of formulating a standard or it may merely pass upon such work when it has already been done, and is free to modify any standard before its adoption. When the Sectional Committee agrees that a standard or code is in acceptable form for final adoption it reports to the sponsor, and if the sponsor body is satisfied with its work and approves it, it so reports to the American Engineering Standards Committee. That Committee then approves the standard as an American Standard, as a Tentative Standard or as Recommended Practice.

The American Engineering Standards Committee has already approved eight standards which may be classed as safety codes, as follows:

- Industrial Lighting Code
- Safety Code for the Use, Care, and Protection of Abrasive Wheels
- National Safety Code for the Protection of the Heads and Eyes of Industrial Workers
- National Electrical (Fire) Code
- National Electrical Safety Code
- Foundry Safety Code
- Power Press Code
- Permissible Explosives

More than twenty other safety codes are now being actively worked upon and some of them are about completed. Almost an equal number in addition have been given preliminary consideration.

It will be apparent from the foregoing that the American Engineering Standards Committee, with the coöperation of the Safety Code Correlating Committee, furnishes the machinery for the formulation of safety codes in a manner which will insure thorough consideration of the merits of proposed rules and thorough consideration of the viewpoint of the various interests which are concerned with safety codes. The actual formulation of such codes may be by a Sectional Committee, by a working sub-committee of such Sectional Committee, or by the technical staff of a sponsor body, but in every case the entire Sectional Committee must pass upon the work and approve the tentative draft of a code before it is submitted to the American Engineering Standards Committee. The Sectional Committees are made up of representatives from the six groups previously mentioned and in the case of safety codes always include some representatives from state departments of labor or industrial commissions. When such codes have been approved by the American Engineering Standards Committee the assurance is given that they have had just as thorough consideration as is ever given locally to the formulation of a state code, and in most cases they will have had wider consideration and criticism; and in adopting such a code any state authority may feel sure that he is putting into effect as reasonable and as complete a set of rules as it is feasible to formulate at the time. Such codes may consequently be taken as models for local adoption and application and there will usually be no good reason for modifying the form in which they have been nationally approved.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

AERONAUTICS

The Reed Solid-Metal Semi-Flexible Propeller, S. Albert Reed. Description of a new propeller which is said to be marketed by the Curtiss Company. It is a semi-flexible, solid, thin one-piece metal propeller of about the same weight as a wooden propeller. It is claimed that it can be twisted to varying pitches and twisted back again, permitting combinations of two-bladed propellers to make four at will and turning at the velocity of sound.

The original article describes in some detail the principles underlying the design and tests made with the propeller, particularly those at McCook Field. (*Aerial Age*, vol. 16, no. 4, Apr., 1923, pp. 182–185, 6 figs., *d*)

Light Plane and Glider Notes. A competition probably to be held some time in September has been arranged for in England for light planes fitted with engines not exceeding 750 cu. cm. capacity.

In this connection it is stated that Barbot has been recently flying at Toulouse, France, with a machine fitted with a 7–10-hp. motorcycle engine. He took it up to a height of about 1500 ft. and made a cross-country flight. It is further stated that the machine requires only 4 hp. to keep it in the air and that the maximum speed is about 60 miles per hour. The machine is called the "Dewoitine."

In England a light plane has been designed by W. O. Manning for the English Electric Company and fitted with a two-cylinder A.B.C. motorcycle engine nominally of 4 hp. but developing about 7 or 8 hp. This machine was tested by Squadron Leader Morris Wright, first in straight flight and then in a flight of seven minutes' duration with satisfactory results.

The "Wren," as this design is called, is an ordinary glider in appearance with enclosed fuselage and a cantilever wing with a pronounced dihedral, and the under carriage nearly hidden in the fuselage. The engine drives directly a tiny tractor screw.

In this glider both the pilot and the engine are in front of the wing and yet the machine is not nose heavy, which may be due to the fact that the tail is set at a large negative angle. (*Flight*, vol. 15, no. 15, 746, Apr. 12, 1923, pp. 199–200, 2 figs., *d*)

Lacierva Autogiro Aeroplane

New Type of Flying Machine—The Lacierva Autogiro. Description of a machine designed by the Spanish inventor Juan Lacierva and tested near Madrid by an officer of the Spanish army.

The "Autogiro," as the machine is known, is not a helicopter. In it the large four-bladed screw which is mounted on the vertical shaft fixed on the fuselage is not actuated by any power plant. Instead it is made to turn freely on its bearings. It is therefore really a wind vane which operates like the small propellers which are used to actuate the fuel pumps of aircraft engines or wireless generators.

This big vane is mounted in ball bearings and is not controlled by the pilot. The blades of the vane are set at a fixed angle of incidence relative to the axis of rotation, but they are hinged to the bearing shaft in such a way that in flight they place themselves in the resultant of their lift and the centrifugal force.

Outside of these vanes the machine is an ordinary tractor aeroplane. The following is given to explain the principles involved in its operation.

It is known from experiments that when a stationary airscrew is exposed to an air current, the blades, being in position *A* (Fig. 1), have a resultant *R* which makes an angle with the airscrew shaft. The resultant *P* of the opposite blade (position *B*) has always a smaller angle than *A* or is negative. Therefore a rotation is established by the airscrew in the sense of the arrow. The speed of rotation will increase until the resultant of *R* and *P* is parallel to the axis of rotation of the airscrew. The whole lifting body does not transmit to its shaft any torque except the one produced by the friction of the bearings, which can be neglected, therefore eliminating the necessity of using two propellers.

However, the resultant velocity of the blades relative to the air in position *A* is greater than in *B* and its lift will be greater also. Therefore the total resultant of this airscrew will not pass through its center and the whole system will tend to bank. This banking effect has been overcome in the Autogiro by fixing the

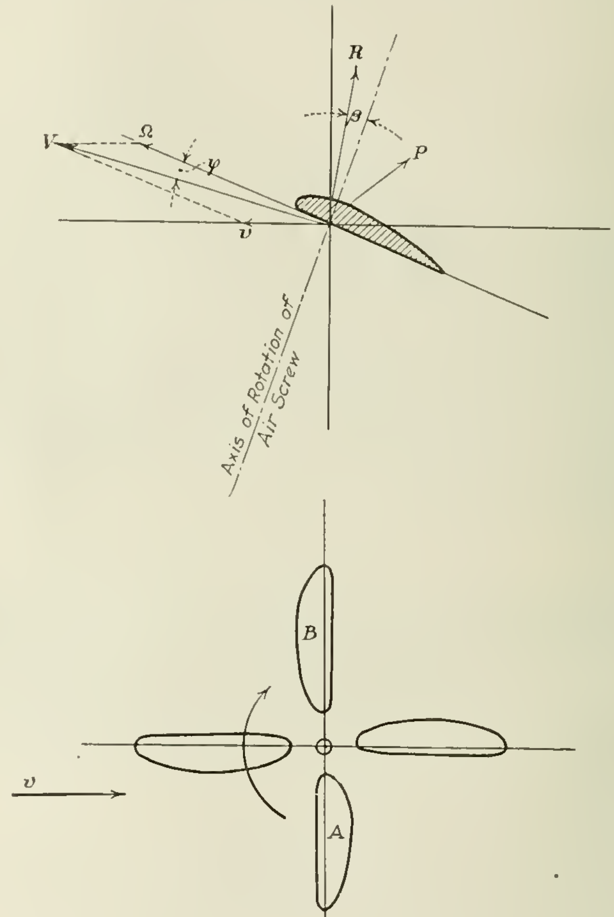

Fig. 1 Wind Vane of the Lacierva Autogiro

blades to the shaft by means of a hinge, which permits them to set themselves automatically in the resultant position of the centrifugal force and lift. In such a way blades *A* will bank slightly, while blades *B* will remain horizontal and the total resultant of the lifting airscrew will always pass through its center.

If we analyze the effect of the hinged blades of the vane, we see that the shaft can freely change its angle with the plane of rotation of the blades, but that the blades have a strong tendency to return to their original position relative to the shaft. This gives an automatically perfect banking in the turns and stability in flying.

The velocity of the blades relative to the air is much greater than the translational speed of the whole machine. The angle of attack is a function of the translational speed of the machine and the angle between its direction of motion and the plane of rotation of the blades. This allows a much greater range of speeds and angles of flying to the whole machine, and will permit landings in very small spaces without horizontal motion.

It is stated that in tests it did land with the engine shut off with practically no forward speed and that it has remarkable stability for it can be flown without assistance of any lateral control while the elevator controls could be locked for any length of time without influencing the behavior of the machine. (*Aviation*, vol. 14, no. 15, Apr. 9, 1923, pp. 397–398, 2 figs., *d*A)

BUREAU OF STANDARDS (See Engineering Materials; Refrigeration)

ENGINEERING MATERIALS (See also Refrigeration)

West African Palm Oil Manufacture and Uses

West African Palm Oil, "Agricola." Down to quite recent years virtually the whole of the palm oil produced in West Africa has been laboriously and crudely prepared by hand labor, chiefly that of women and girls, while the quality of the product has been admittedly below attainable standards; moreover, it has long been known that enormous quantites of oil are lost annually in consequence of the wasteful methods adopted.

The situation would seem to present a splendid opportunity for the introduction of machinery, and it is remarkable that only within the last decade or so have serious attempts been made to tackle the question.

At the present time, however, serviceable machinery is being employed which removes the pericarp from the fruits, the oily pulp being then transfer ed to presses where the expression of the oil is effected under controlled conditions of temperature.

The employment of such machines effects great economies in production, and also results in the production of a clean oil of good, dependable quality. So far, plant of this kind is almost entirely in the hands of European companies.

The palm "nuts" which were separated from the oily pericarp, and set aside for subsequent treatment, have now to be dealt with in order to obtain the kernels.

As the first step, the nuts are spread out in the sun for a week or more in order to cause the kernels to shrink from the shells and so render their removal easy.

The subsequent procedure, however, is almost incredible. Millions upon millions of palm kernels are exported from West Africa every year, yet, until comparatively recently, every single kernel has been obtained by the deliberate cracking by hand, between two pieces of stone, of the separated individual nuts, one by one, followed by the picking out, separately, of the individual kernels.

Effective machines for this purpose are now available, but in spite of their increasing use (chiefly by European undertakings), the great bulk of the palm nuts are still cracked by hand.

The kernels are collected and shipped to Europe where the oil is obtained either by pressure in machine presses, or extracted by solvents from which the oil is obtained subsequently by evaporation.

The nut shells form a good fuel, but at present have no regular industrial use. During the war, however, palm-nut shells (as in the case of cocoanut shells) were largely used for the manufacture of a charcoal which was found to be admirably suited for use in gas masks as an absorbent of noxious fumes.

The primary value of palm oil to the West African native is as a foodstuff which is chiefly used as an oily basis for the preparation of soups, stews, and dishes of all kinds; and "palm-oil chop" is familiar enough to Europeans on the Coast.

The oil used for this purpose is usually carefully prepared from fresh fruit, and has considerable dietetic value. When fresh it has an odor of violets, and is much appreciated by the natives.

In certain districts the natives are also acquainted with the use of the oil for making soap, which they prepare by mixing the oil with ashes obtained by burning banana leaves. This fact is interesting, since the manufacture of soap and candles is one of the chief uses to which palm oil is put in industrial Europe, especially in this country, where enormous quantities are employed for soap making.

Another important use is in the Welsh tin-plate trade, where palm oil (commonly mixed with cottonseed oil and certain mineral oils) is extensively used for coating the heated iron plates previous to the "tinning" process, in order to prevent oxidation. It will also be remembered that, as mentioned in a recent issue of *Imperial Commerce*, oil engines have now been designed which successfully use palm oil as a fuel.

The oil from the kernels (palm-kernel oil) finds somewhat different uses. Like palm oil it is solid fat (white) at temperatures obtaining in this country. Relatively small quantities of the kernels are used locally, the bulk being exported.

Before the war this trade was very largely in the hands of Germany, as is shown by the fact that in 1913 of a total export of 174,720 tons of palm kernels from Nigeria, valued at £3,109,820, no less than 131,886 tons, valued at £2,405,624, were sent to Germany, the British import being only 30,345 tons valued at £511,541. Further, Germany in the same year obtained an additional 100,000 tons of kernels, worth over £1,000,000 from other West African countries, British and foreign. During the war, however, the kernels were sent to this country and an important trade in them has been built up which it is hoped will be retained.

Two products are obtained from the kernels, viz., white palm-kernel oil, and oil cake.

The oil has a pleasant nutty taste and is used not only for making soap and candles but also to an increasing extent for the manufacture of margarine, vegetable butters, cooking fats, and fats used in making chocolates and confectionary. The oil is well suited for margarine, and it is estimated that probably 40,000 tons are now used annually in Europe for this purpose.

The oil cake is a most valuable feeding stuff for live stock and is especially useful as a food for dairy cattle, for which purpose it was highly prized in Germany and other European countries. In this country, however, it is by no means widely known. (*Imperial Commerce and Affairs*, Aug., 1922, abstracted from a publication of the Bureau of Foreign and Domestic Commerce, Department of Commerce, 9 pp., *gd*)

Chromizing

Chromizing, F. C. Kelley. Paper giving a brief summary of the work which has been done to date on the diffusion of metals in the solid state and describing in detail the process of chromizing and its effects on the physical and chemical properties of iron.

The method of chromizing described by the author is somewhat similar to the well-known process of calorizing and depends upon the property possessed by many metals of diffusing at temperatures below their melting points.

The process consists of packing the material to be treated into a powdered mixture of alumina and chromium. The amount of the material used in the mixture is 45 per cent of alumina and 55 per cent of chromium by weight. The material is usually packed into a tube of iron, and then heated at 1300 to 1400 deg. cent. in hydrogen, in vacuum, or in some neutral atmosphere for a length of time depending upon the penetration and concentration of chromium desired. Certain precautions as to the presence of oxygen and water vapor have to be observed.

The furnaces used for this work consist of alundum tubes wound with molybdenum wire as a heating wire. These tubes are placed in a suitable furnace casing and surrounded with alumina powder, which acts as a heat-insulating material. The chief use for these furnaces thus far has been in the chromizing of turbine buckets, which latter have been installed in various turbines throughout the country in order to test them for corrosion under actual operating conditions.

The structure of the metal is next discussed and illustrated by photomicrographs. In order to get the best results it is necessary to use an iron or steel of low carbon content, as iron of high carbon content does not chromize well. The difficulties of the process are discussed and data given as to the penetration of the chromium into the material.

As regards resistance to corrosion, chromized-iron samples were tested alongside with sherardized samples and gave equally good results.

The samples under test showed up so well that additional tests upon turbine buckets were made. These chromized nickel-steel buckets proved so satisfactory that it was decided to put them into various turbines throughout the country, and into some of the turbines of ocean-going vessels. The best comparison of

resistance to corrosion of chromized and unchromized turbine buckets under service conditions is illustrated in a figure in the original paper. These buckets were run side by side in the same wheel of a turbine for one year. The unchromized nickel-steel bucket had its edge entirely corroded and eroded away, and in addition the face of the bucket was badly corroded. The chromized bucket was in perfect condition, showing no signs of corrosion.

In cases where the chromized material must stand high tension and fatigue stresses, the high temperature of chromizing lowers the resistance of the material to these stresses, but by proper heat treatment the original properties may be almost entirely restored.

Carbonizing of chromized iron lowers its resistance to corrosion, and polished samples of chromized iron which have been case-hardened will show numerous globules of water if allowed to stand in the open air for only a short time.

Chromized iron itself is quite soft and ductile, but by case-hardening and heat treatment it may be made very hard.

Chromized-iron samples were tested in 10 per cent HCl, HNO_3, and H_2SO_4. They stood up for five months in the 10 per cent HNO_3 without discoloring the solution or showing any signs of attack, but they broke down almost immediately in the other two acids.

In addition to these characteristics, chromized iron has a silver color, it takes a high polish, and the most remarkable thing about it is its softness, even where large percentages of chromium are present.

Chromium may be applied to other metals besides iron and may be used for purposes other than preventing corrosion. (Paper presented before Forty-third General Meeting of the American Electrochemical Society, May, 1923. Abstracted from advance copy, pp. 233–250, 8 fig., *eA*)

Lathe Breakdown Tests of Some Modern High-Speed Tool Steels, H. J. French and Jerome Strauss. This report is concerned with comparisons of performance of modern high-speed tool steels in so-called "lathe breakdown tests," in which endurance of tools is measured under definite working conditions, and likewise with the limitations of this method when applied to the purchase of steel. The modern steels are first classified according to chemical composition, and this division is made use of in discussion of results obtained.

Important features developed or conclusions drawn may be summarized as follows:

1 Breakdown tests are not satisfactory as the basis of purchase for high-speed tool steels.

2 While competitive comparison of brands of nearly similar performance are not justified, owing to the qualitative nature of this type of test, relatively large differences may be ascertained with certainty, provided sufficient tools are tested and averages of at least two grinds are used in the interpretation of results.

3 In certain severe breakdown tests with roughing tools on 3 per cent nickel-steel forgings, in which high frictional temperatures were produced, it was found that the performance of commercial low tungsten-high vanadium and cobalt steels was superior to that of the high tungsten-low vanadium type, and special steels containing about $^1/_4$ per cent uranium or $^3/_4$ per cent molybdenum. The average power consumption in all cases was practically the same, so that this factor need not be introduced in comparisons which may be made on the basis of endurance of the tools.

4 Modification in test conditions, including small changes in tool angles but principally changes in cutting speed, more markedly affected the performance of steels containing cobalt or special elements such as uranium or molybdenum than that of the basic types (plain chromium-tungsten-vanadium steels).

5 The relatively poor endurance of the high-tungsten steels under severe working conditions was not observed in more moderate tests which were made on the same test log with equal cutting speed and depth of cut but with reduced feed, and in which the frictional temperatures produced were not so high. Also in these latter tests the performance of the cobalt steels was better than that of either the low- or high-tungsten steels.

6 Hardness determinations and examination of fractures indicate that the various types of commercial high-speed steel show differences in behavior under heat treatment and in physical properties which probably are of importance under moderate working conditions, and might counterbalance slight advantages in performance. (Abstract of *Technologic Paper of the Bureau of Standards*, No. 228, *e*)

Solders for Aluminum. All metals or combinations of metals used for aluminum soldering are electrolytically electropositive to aluminum. A soldered joint is therefore rapidly attacked when exposed to moisture and disintegrated. There is no solder for aluminum of which this is not true.

Joints should therefore never be made by soldering unless they are to be protected against corrosion by a paint or varnish, or unless they are quite heavy, such as repairs in castings, where corrosion and disintegration of the joint near the exposed surface would be of little consequence.

Solders are best applied without a flux or by using paraffin as a flux, after preliminary cleaning and tinning of the surfaces to be soldered. The composition of the solder may be varied within wide limits. It should consist of a tin base with addition of zinc or of both zinc and aluminum, the chief function of which is to produce a semi-fluid mixture within the range of soldering temperatures.

Suggested Ranges of Composition

Tin-Zinc Solders:	
Tin	remainder
Zinc, per cent	15-50
Tin-Zinc-Aluminum Solders:	
Tin	remainder
Zinc, per cent	8–15
Aluminum, per cent	5–12

The higher the temperature at which the "tinning" is done, the better the adhesion of the tinned layer. By using the higher values of the recommended zinc and aluminum percentages given above, the solder will be too stiff at lower temperature to solder readily and the workman will be obliged to use a higher temperature, thus securing a better joint. A perfect union between solder and aluminum is very difficult to obtain.

The joint between previously tinned surfaces may be made by ordinary methods and with ordinary soft solder. Only the "tinning" mixture need be special for aluminum.

There is no reason why a good solder for aluminum need be brittle as several commercial varieties are, and it is very undesirable that it should be.

The tensile strength of a good aluminum solder is about 7000 lb. per sq. in.; those with higher tensile strength have, in general, their temperature of complete liquidation too high for soldering purposes. The strength of a joint depends upon the type and upon the workmanship. Much dependence should not be placed on the strength of a joint. (*Circular of the Bureau of Standards*, no. 78, Mar. 20, 1923, 14 pp., 7 figs., *dp*)

Some Tests of Steel Wire Rope on Sheaves, Edward Skillman. Tests on wire ropes on sheaves, to determine their strength under static load, were made on sizes $^5/_8$, $^3/_4$, $^7/_8$, 1 and $1^1/_4$ in. in diameter. They were all of 6-strand, 19-wire construction, made from "plow" steel.

It was found that the strength was less than that of the straight rope having socketed ends. Considering the strength of the straight rope as unity, the strength of $^5/_8$-in. rope on 10-in. sheaves was 87.4 per cent and on 18-in. sheaves 95.3 per cent, while $1^1/_4$-in. rope had a strength of 75.8 per cent on 10-in. sheaves and 84.7 per cent on 18-in. sheaves. The other sizes had corresponding values.

Tensile tests of wires from the ropes showed that the wires had the high strength of 230,000 lb. per sq. in., an elongation of 2 per cent, and a reduction of area of about 46 per cent. The strength was practically the same for all series of the wires.

The strength of the straight ropes followed closely the equation $S = 83{,}000\ d^2$, in which S is the strength in pounds and d the diameter of the rope in inches.

One worn rope which was tested showed a surprisingly high strength when its condition is considered.

A point of inflection in the load diagrams was found at from 56 to 65 per cent of the ultimate load, above which the elongations increased rapidly.

A wire rope under tensile load undergoes considerable elongation and reduction of diameter. The total elongation near the ultimate was about 2.5 per cent after repeated loads.

The modulus of elasticity of steel wire rope may be assumed to be about 8,500,000 lb. per sq. in. for new rope loaded a number of times to one-fifth its ultimate strength.

Some conclusions are drawn upon the effect of heavy loads in squeezing lubricant out of the core of the rope and the wear which follows. (Abstract of *Technologic Paper of the Bureau of Standards*, No. 229, *c*)

FUELS AND FIRING

The Utilization of Lignite, Prof. Bancroft Gore. A review of the fuel situation in South Dakota, showing the necessity of substituting lignite to replace costly eastern coals. An account is given of experiments made at the Mining Experiment Station in burning lignite in dust form, both dried and undried, to determine the best combustion conditions. The use of unit pulverizers for central heating stations, small power plants, laundries, etc., is advocated and illustrations of several types adapted for this work are presented. The expediency of upgrading lignite at the mine by crushing, followed by drying and removal of dust on impact screens, is emphasized and shown to be an important factor in adapting this fuel for both domestic and industrial purposes.

The lignite received at the Mining Experiment Station of the State School of Mines at Rapid City, South Dakota, from the State Mine, showed a B.t.u. content varying from 7312 as received to 10,744 on a dry basis. It has a high water content and a tendency to break down into fine particles and even powder on air drying. It is softer than any other type of coal. Its main impurity is water.

As regards burning lignite as dust, it is claimed that it is an almost ideal substance to start with as it pulverizes easily and is high in volatile matter. It is interesting to note that as found accidentally by one investigator, lignite coal with as high as 17 per cent moisture was readily pulverized and burned in dust form.

As regards the cost of drying lignite at the mine, data are presented from an estimate prepared by the Ruggles-Coles Engineering Co., who claim that the total cost per short ton of dry coal at the mine is 25.5 cents.

One of the features of the experiments made at the Mining Experiment Station was that after the furnace had been brought to a high heat it was fed with undried lignite having a moisture content of 31.93 per cent. The feed was increased to provide the same quantity of actual combustible matter. The results were so satisfactory that subsequent tests were made on the undried crushed coal, with the exception of special tests or intervals of tests where the highest possible temperature was sought. So far as the author is aware, this is the first record of burning in dust form crude lignite slack containing the original moisture content as received.

The article contains interesting data on the velocity of dust jet carburetion and, in particular, on the dust firing of wet lignite. (*The Black Hills Engineer*, vol. 11, no. 2, pp. 85–126, 24 figs., *epA*)

Stoking Anthracite Culm and Gashouse Tar, Joseph Harrington, Mem. A.S.M.E. Description of the installation at the plant of the Consolidated Gas and Electric Co., Long Branch, N. J., for burning a mixture of anthracite culm and liquid tar from gas producers on forced-draft chain-grate stokers without any modification of the furnaces.

The furnace had a total furnace volume of 7.7 cu. ft. per sq. ft. of grate area, and 0.25 cu. ft. per sq. ft. of heating surface. It was of conventional design, and with bituminous coal was smokeless and admitted of ratings up to 250 per cent without destructive temeratures.

The material used accumulated as waste in such quantities as to become a nuisance. With the installation described here it proved to be feasible to use it as a fuel with loads up to 225 per cent of rating, it being possible even with this fuel to carry the loads well over the peak and still have a fair margin to spare.

The material initially had the appearance of a load of asphalt and sand such as is used for the surfacing of macadam roadways. Stepping on this material would pack it into a soggy mass, and precautions had to be taken to prevent such consolidation.

Ready surface ignition was anticipated, but what would happen thereafter could not be predicted. It was feared that the tar would be driven down by the heat of the fire into a more liquid state and render the lower layers of the fuel bed so dense that no air could pass up through. This proved, however, to be wrong. A strong pressure was maintained in the front compartment for the purpose of overcoming any such tendency, and with apparent success, since the mixture ignited with readiness right up to the gate and combustion proceeded with great density until the fuel had progressed approximately one-half the length of the grate. At this point apparently all the tar was burned out, leaving a porous bed of fine anthracite of uniform texture which burned much as any anthracite fire burns. In other words, there were short tongues of flame shooting up through the fuel, a volume of transparent monoxide gas at the surface burning to a complete CO_2 product in the upper part of the furnace. Smokeless combustion resulted, and in due course the anthracite culm had all burned down to a perfect ash.

Draft in the furnace was maintained as usual at a point near neutrality. The pressures in the stoker compartments, of which, in this instance there are four, were maintained much as usual with anthracite fuel, except that care was taken to keep the front compartment under full pressure, which, in this instance, averaged about two inches. The second compartment, where the most active combustion took place, was maintained under high pressure, although of slightly less degree, and the third compartment stepped down to perhaps half an inch. The fourth compartment was cut down sometimes to zero, and sometimes to a quarter of an inch according to the appearance or disappearance of fuel over the compartment. (*Power*, vol. 57, no. 14, Apr. 3, 1923, pp. 523–524, 3 figs., *d*)

HANDLING OF MATERIALS

Coal Handling by Suction at the Brimsdown Power Station of the North Metropolitan Electric Power Supply Company. The pneumatic system described is designed to perform three distinct handling operations by means of the one receiver and vacuum pump.

Coal can be discharged from barges lying in an arm of the canal alongside the station at the rate of 50 tons per hour, or, by means of a simple linking up of piping, can be taken from the dumps and conveyed to the bunkers. Further, provision has been made for withdrawing coal from a hopper below a railway track, and this will be put into operation as soon as the siding is completed.

The greatest distance which the coal is taken by the pneumatic plant from the dumps to the coal bunkers is approximately 350 ft., and from the canal arm to the nearest point of the bunkers is 115 ft. The fuel dealt with is usually washed small coal up to $1^1/_2$ in., but at times rough slack is also handled.

The coal lifted by the intake pipes is delivered into a receiver which discharges through an oscillating tippler to an automatic weigher, whence the coal is delivered to the belt conveyor arranged with a traveling throw-off carriage for feeding the overhead bunkers. The air from the receiver passes through a high-vacuum-type textile-sleeve suction filter which collects the dust, after which the air is run direct into the pump.

The article describes the installation in considerable detail. The pump is of a design (Simon) in which the valves are situated around the outside of the cylinder head, the cylinder being divided into two parts, the inner liner and the outer casing, one side of which is used for exhaust and the other for suction. The piston is fitted with rings having a special system of dry lubrication which has been found most suitable for this class of work; all of the moving parts of the pump are fitted with sight-feed lubricators.

In a recent test of the plant the average capacity during barge discharging, including all trimmings, was over 50 tons per hour, with a maximum rate of 56 tons per hour. (*Iron and Coal Trades Review* vol. 106, no. 2873, Mar. 23, 1923, pp. 426–427, 5 figs. *d*)

INTERNAL-COMBUSTION ENGINEERING

Internal-Combustion Engineering Characteristics of the Vertical Eight, P. M. Heldt. New developments in eight-in-line engines probably will take place in the United States within a few months. The author discusses this type with particular reference to questions of torque, balance, and crankshaft design.

As regard the latter, the author indicates two basic rules for the design of crankshafts for eight-cylinder vertical engines and works out a number of designs that will give equally spaced explosions and no rocking couple, and then proceeds to the discussion of the various designs from the point of view of ease of manufacture. He shows mathematically that in a straight-line eight-cylinder engine the inertia forces are balanced out. Therefore, as far as balance of the reciprocating parts is concerned the eight-cylinder vertical engine is equal to the six-cylinder vertical and twelve-cylinder V-type, and superior to the eight-cylinder V-engine. (*Automotive Industries*, vol. 48, no. 15, Apr. 12, 1923, pp. 817–820, 10 figs., *eg*)

MACHINE PARTS

Roller Bearings on Railroad Cars

The Stafford Roller Bearing for Railway Cars. Description of a bearing which has been in successful operation for a number of months on several cars of the Michigan Central Railroad. It has been applied in a six-wheeled truck running under an American Railway Express car and also to an 80,000-lb.-capacity box car and a flat and gondola car of the same capacity. It is

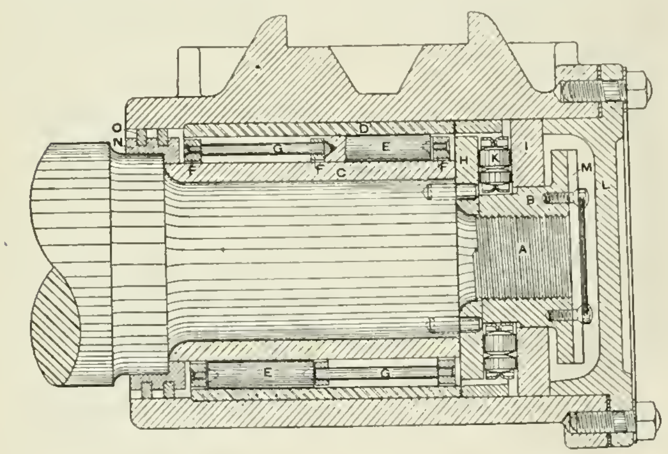

Fig. 2 Vertical Section of Stafford Roller Bearing

stated that these cars traveled a total of 8375 miles after the bearings had been applied. Practically no repairs had to be made to any of these bearings.

The principal claim made for the bearing is the great reduction in resistance effected by its use. While no dynamometer tests have yet been made with cars equipped with this bearing, there is one rough test that may be used to obtain an approximate idea of its possibilities. The flat car already alluded to was loaded with axles until the gross weight amounted to 122,600 lb. and one man was able to push this car on a level track.

The construction of the bearing in its essential parts is shown in Fig. 2. Essentially it consists of a set of horizontal rollers held in a cage to take the vertical load and another set held in another cage to take the end thrust of the axle.

The axle is turned with the ordinary dust-guard seat and journal bearing, the latter having a very generous fillet at the inner end. At the outer end, however, instead of the usual collar there is a projection *A*, which is threaded to take the adjusting nut *B*. In distinction from other roller bearings that have been tried, the turned surface of the axle journal is not used as a raceway for the rollers, but is protected by an inner bushing *C* which is made of high-carbon, high-chrome special roller-bearing steel which is ground and polished on both sides and then pressed on to the journal with a pressure of 4 tons.

The journal box is made to fit the ordinary truck pedestals, whether for trucks having those of the regulation pattern for passenger cars or merely bolts as in the diamond type of freight truck. Its interior, however, is bored to a circular form to meet the requirements of the roller bearing. Like the axle it is provided with a raceway in the form of an outer bushing *D*, which is of the same material as that used on the axle; and is ground and polished on both surfaces and pressed into place with a pressure of 12 tons.

It is between these two bushings that the rollers *E* work. These rollers are held in the cage *F* which is formed of three rings held together by the spacing rivets *G*. These rivets, like the rollers, are staggered in the two sections of the cage, as will be clearly seen in the reproduction of the photograph of this part assembled. The rollers themselves are held in place on 60-deg. centers or trunnions which set into corresponding 70-deg. centers cut in the ends of the rollers. This allows a clearance of 10 deg. for lubrication and also prevents any friction between the trunnions and the counterbore in the ends of the rollers, which latter is 1/4 in. deep. The remaining part of the rollers is solid.

The end thrust is taken by two plates *H* and *I* with the rollers *K* between them. The plate *H* is provided with dowel pins that fit into the axle by which the two are made to turn together. The inner thrust bearing plate *H* is held in place by the adjusting nut *B* which is screwed tightly against it. The outer thrust bearing plate *I* is held in place by the inside diameter of the journal box, into which it is fitted, there being a clearance between it and the adjusting screw on the inside. It (*I*) is held up against the rollers *K* by an inwardly projecting ring cast solid with the box cover *L*. This journal-box cover is so adjusted that the pressure which it exerts through the outer thrust bearing plate against the end-thrust bearing rollers is neither too heavy nor too light. In short, these parts are so manufactured that the pressure against the thrust-bearing assembly or parts is neither too light nor too heavy.

The adjusting nut *B* is locked by the locking bar *M* which fits in the slot in the nut that can be seen in the reproduction of the photograph, and in a corresponding slot in the end of the axle. The locking bar is itself held in place by two tap bolts that are screwed in to the adjusting nut and are prevented from turning by running a wire through small holes in their heads and tying them together. (*Railway and Locomotive Engineering*, vol. 36, no. 4, Apr., 1923, pp. 102–104, 4 figs., *d*)

The Process of Gear Grinding and a Discussion of Tooth Form. Glenn Muffly. The author claims that ground gears are more durable, probably because they cause less vibration. He also contends that grinding is justified on the cost basis because fewer tear-downs are required and no finishing cut need to be taken iu machining.

According to the author, it is now possible to make gear teeth so accurate that it is necessary to consider the deflections under load and so form the tooth as to compensate for even this minute deflection if the maximum silence is to be desired. He also calls attention to the need for accuracy from tooth to tooth, that is, of having each tooth identical in size and contour. There is a possibility of gears being accurate when measured for perhaps one-half the circumference of the gear, but when the measurements from tooth to tooth are considered, the gear is sometimes very inaccurate. This would result in a noisy installation, although by some methods of checking the gears would appear to be exceptionally good.

Looking ahead at the possibilities which may be realized through gear grinding, the author points out that if real quietness can be secured, in the transmission gears, for instance, there might well be a tendency toward overgeared four-speed gear sets. With traffic conditions as they now exist in large cities there is more gear changing, and if quiet gears can be secured it will be possible to narrow the engine speed range and consequently increase the economy of the vehicle. He cites the Citroën car which with a four-speed gear box is reported to have obtained mileages as high as 40 per gal.

Another possible effect of accurately ground gears is the return from helical to straight-tooth spur gears for timing purposes.

The grinding time per tooth can be very quickly calculated. As an example, on a 15-tooth gear taking one cut per tooth the

time averages 14.4 sec. per tooth; on a 21-tooth gear, 9.6 sec., and on a 29-tooth gear, 8.4 sec. These figures refer to 6–8 pitch gears.

The grinding process employed is a wet grinding, hence the heat generated does not draw the gear material.

In the case of one type of gear set it has been found that after 38,850 teeth had been ground on both sides, with two cuts to each side, the cost was $1.75 per gear set.

It makes little difference how close the center distances are held, but the shafts must be parallel. It must be remembered that shafts are not necessarily parallel even when the distance between them at each end is exactly the same.

The stock left for grinding after the rough cut on the gear averages from 0.002 to 0.003 in. on 8–10 pitch gears.

It is not advisable to grind both sides of the gear at once as it brings in too many factors which must be kept synchronized. The maximum variation for backlash in these ground gears is 0.00025 in. (Paper read before the Detroit Section of the Society of Automotive Engineers in April, 1923. Abstracted through *Automotive Industries*, vol. 48, no. 15, Apr. 12, 1923, p. 809, *pg*)

Six Kinds of Riveted Joints. According to E. E. Rohrer, of the Coatesville Boiler Works, there are in general six types of riveted joints. First, the lapped and single-riveted seam is almost entirely used for storage-tank work. The efficiency of this type of seam is approximately 50 per cent. Second, the lapped and staggered double-riveted seam, used where medium pressure may be required. The rivets in this type of seam usually have about 1 in. greater pitch than those in the single-riveted seam. This type of joint has an efficiency of about 70 per cent. Third, the lapped and triple-riveted seam, which is comparatively seldom used. Fourth, the butt-strapped double-riveted seam (the butt-strap seams here mentioned have inside and outside butt straps) has an efficiency of about 82 per cent. Fifth, the butt-strapped triple-riveted seam, having an efficiency of about 87 per cent. Sixth, the butt-strapped quadruple-riveted, having an efficiency of about 93 per cent. These latter two are used on larger diameters and for higher pressures. (*Chemical and Metallurgical Engineering*, vol. 28, no. 15, Apr. 16, 1923, p. 679, *g*)

Power of Worm Gearing, Arnold A. Arnold. The author discusses the various formulas for the power which worm and worm-wheel gearing will transmit, and in this connection the formulas derived from Bach and Roser's experiments published in the *Zeitschrift des Vereines deutscher Ingenieure*, Feb. 14, 1903; Unwin's formula (Machine Design, vol. 1); and those in Oberg's Spiral and Worm Gearing.

These formulas, the author claims, are not quite suitable for ready calculations as they involve the use of logarithms. He therefore gives four diagrams showing the relation between the horsepower transmitted, the pitch of the worm threads or worm-wheel teeth, the maximum permissible pitch-circle diameter of the worm, and the revolutions per minute of the worm, all these diagrams being based on the formulas referred to above. These diagrams apply only to single, double, treble and quadruple worm threads within certain limits of revolutions. (*Mechanical World*, vol. 73, no. 1890, Mar. 23, 1923, pp. 184–186, 4 figs., *g*)

MACHINE SHOP (See also Engineering Materials)

Experimental Machine Building—Pictorial Assemblies

Controlling Costs in Building Experimental Machines, Fred H. Colvin. The second article of a series, showing how tools are to be decided upon and the operation times set. Among other things, the article describes so-called pictorial assemblies, the pictures being sketches in perspective which show the design of the piece, so that there can be no mistake as to what it looks like. This is particularly useful when it comes to assembly work. An example is given in Fig. 3 which shows a unit assembly of a controller. This consists of seven sub-assemblies, one of each being required for the complete unit. Each sub-assembly is numbered and full details of it can be found under that number. Each of the sub-assemblies may be represented by a special pictorial assembly, which, in its turn may include minor sub-assemblies, as is, for example, the case with the sub-assembly No. 3192

The assembly sheets may be, however, a good deal more complicated than that shown in Fig. 3. For example, one of the illustrations in the original article shows a complete assembly of a separator involving a number of sub-assemblies, and finally one

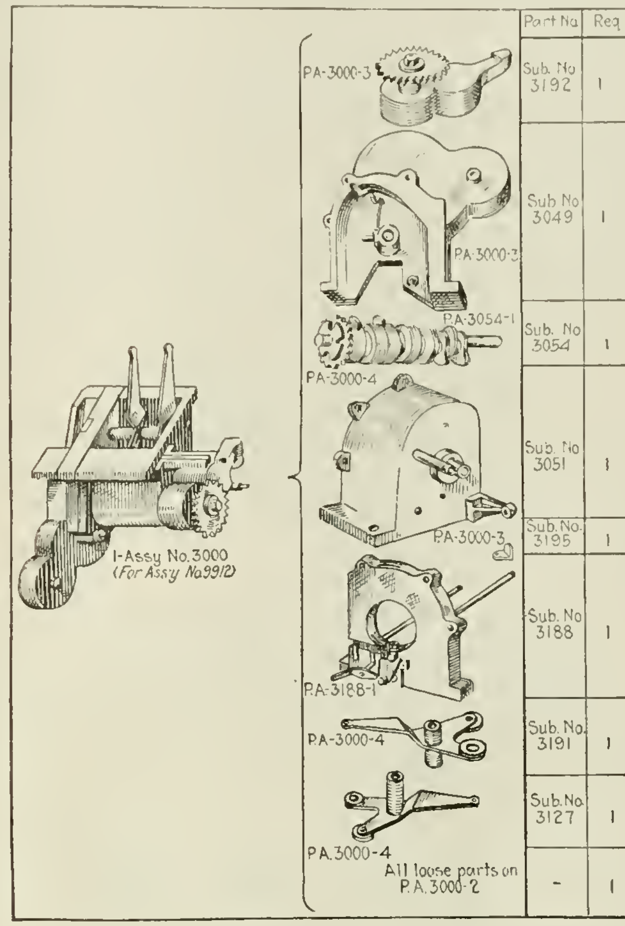

Fig. 3 Pictorial Assembly of Controller Unit

assembly which shows a complete machine comprising five separators, a carrying unit, loader connections, etc.

Such assembly drawings are valuable in that they leave little room for error and make it possible for mechanics to assemble a machine without difficulty, even if they are not especially familiar with the machine. (*American Machinist*, vol. 58, no. 14, Apr. 5, 1923, pp. 503–507, figs. 3–14, *dp*)

MANAGEMENT ENGINEERING (See Machine Shop)

METALLURGY (See Engineering Materials)

MOTOR-CAR ENGINEERING (See also Internal-Combustion Engineering)

Large-Section Tires on Passenger Motor Cars, Herbert Chase. Important results are expected from the development of a so-called "balloon" tire, which is essentially a tire of the same outside diameter as those in use at present but of much larger section and fewer plies. This is accomplished by using a smaller rim diameter. For example, in place of a 33 by 5-in. 8-ply cord tire on a 32 by $4\frac{1}{2}$-in. rim 23 in. in diameter, is used a 34 by 7-in. 4-ply tire on a 29 by $4\frac{1}{2}$-in. rim 20 in. in diameter. Instead of a pressure of 65 lb. the new tire operates at 25 lb. inflation pressure.

The results are said to be very remarkable. In the first place, road inequalities are transmitted to a far lesser extent than with ordinary tires. The brakes become more effective, and slipping and skidding on wet pavements are largely eliminated. There are not enough data available to show the comparative wearing qualities of the conventional type of cord tire and the newer type

which is also of cord construction. The use of the new-type tire is claimed to result in saving in unsprung weight and, consequently, in a secondary saving by way of lesser impact on the road surface.

The new large-section tires with their lower inflation pressure absorb a much larger proportion of the shock due to the road inequalities. There is less fatigue to the operator and also less vibration transmitted to the chassis, which makes the cars quieter in operation. It is claimed that the use of new tires increases the maximum speed of the car and lowers its fuel consumption. On the other hand, however, it is pointed out that when the car is traveling at high speed there is an increased danger of accident due to blowout because of the thinner wall of the tire.

Among the disadvantages may be mentioned the necessity of changing the design of the chassis, for approximately the same diameter of large-section tire will have less side clearance in relation to body and chassis parts. In some cases this might require a decrease in the width of the rear seat and a decrease in the width of the chassis at the front in order to enable the use of the same steering lock and to maintain the same turning radius.

It is said that a number of prominent car manufacturers are said to be seriously considering the adoption of 34 by 7-in. or 32 by 6-in. tires as standard equipment in the near future.

The article is accompanied by expressions of opinion from several car and parts manufacturers, as well as from various tire companies who have been doing work along this line. (*Automotive Industries*, vol. 48, no. 15, Apr. 12, 1923, pp. 812–816, *dg*)

POWER-PLANT ENGINEERING

Solar Power Plant—Design and Costs

The Berland-Caufourier Solar Power Plant, P. Caufourier. There have been many attempts to utilize solar heat for power generation, of which the author mentions and briefly describes the Mouchot, Tellier, and Shuman projects, the last being the only one to be applied for actual work. (See Journal A.S.M.E., vol. 37, 1915, p. 661.)

The present installation is a combination of the Caufourier self-vaporizer for generation of steam from water at temperatures of 50 to 75 deg. cent. and the Berland system of mirrors. The Caufourier self-vaporizer was initially designed for purposes of power generation from natural hot waters and was described in Mechanical Engineering, vol. 43, no. 3, March, 1921, pp. 200–201.

The Berland solar receiver, as the apparatus is called, is shown in Fig. 4. It is a mirror shaped as a parabolic cylinder—similar to the mirrors in the Shuman Egyptian installation, yet differing therefrom in certain essential points. The axis instead of being horizontal is parallel to the axis of the earth and hence in the Sahara has an inclination of 25 to 30 deg. to the horizontal. Under these conditions the solar rays are normal to this axis at the equinoctials and even at solstices their inclination does not exceed 23 deg. The apparatus is therefore better capable of receiving the insolation (solar radiation) than if it had a horizontal axis, and furthermore the inclination to the horizontal favors a natural circulation of the water. The angle of inclination of the solar rays remains constant throughout the day period, provided the mirror has a movement of uniform rotation, which may be automatic. To effect this the mirror is mounted in a series of large circular tracks traveling on rollers, as shown in Fig. 4, where E is the driving gear, G the rollers, C the rolling track, M the parabolic metal mirror, T the boiler tube—which may be of copper or aluminum with a black exterior face, and V a glass sleeve. The frame supporting the mirror is not shown. The boiler tube T is enclosed in one or two glass cylinders, the purpose of which is to prevent dark heat radiating from the tube and thus to reduce the heat losses therefrom. This particular feature was first proposed by Mouchot. The air between these glass cylinders and the boiler tube is partly exhausted in order to reduce convection losses.

According to calculations made by the Swedish scientist Svante Arrhenius, 1 sq. m. (10.764 sq. ft.) of the great circle of the terrestrial sphere receives 25 calories of solar heat per minute. Taking into account the inclination of the solar rays and atmospheric absorption, 1 sq. m. of the mirror will receive from 8 to 9 cal. per min., and as the efficiency of the mirror is of the order of 60 per cent as shown by tests made on the Cairo installation, the water in the boiler tube is capable of absorbing, roughly, 300 cal. per hr. per sq. m. of mirror surface.

On the other hand, if we assume that the water is heated to 90 deg. cent. in the solar receivers and reduced to 80 deg. in the self-vaporizers, the production of steam will equal 18 kg. per cu. m., equivalent to 3.18 i.hp., or 2.5 hp. on the turbine shaft, figuring the condenser at 25 deg. cent. The author further shows that the mirror surface would have to be 18 sq. m. per hp.

The solar power plant illustrated in Fig. 5, will therefore comprise—

1 A sufficient number of Berland solar receivers

2 One or more intermediary reservoirs

3 A sufficient number of self-vaporizer steam generators

4 A water circulation pump and a vacuum pump

5 A superheater, which is essential for drying the steam and at the same time increasing its temperature and hence the Carnot efficiency. A superheat of 35 to 40 deg. cent. would appear to be sufficient. This is the only part of the apparatus that will consume fuel

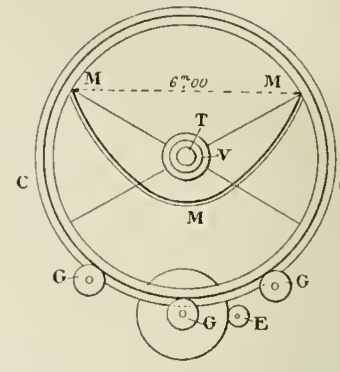

Fig. 4 Berland Solar Receiver

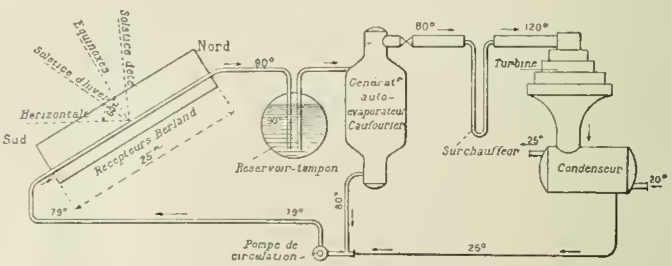

Fig. 5 Diagram of a Solar Power Plant of the Berland-Caufourier Type

(*Sud* = south; *Solstice d'hiver* = winter solstice; *Equinoxes* = equinoctials; *Solstice d'ete* = summer solstice; *Nord* = north; *Recepteurs Berland* = Berland solar receivers; *Reservoir tampon* = intermediary reservoir; *Generateur auto-evaporateur Caufourier* = Caufourier self-vaporizer steam generator; *Surchauffeur* = superheater; *Pompe de circulation* = circulating pump; *Condenseur* = condenser.)

6 A reciprocating steam engine, or still better, a steam turbine

7 A condenser with its auxiliary equipment.

In the climate of southern Algeria the average time the installation is capable of operating is 10 hr. per day, 330 to 340 days per year, and it is proposed to use the power generated primarily for pumping water for irrigation purposes and also for generating comparatively small amounts of power for lighting and industrial power.

In order to deliver power continuously it will be necessary to have a number of solar receivers approximately double the power of the evaporators, and an intermediary reservoir of sufficient dimensions and properly protected against heat losses.

The condensers will use the irrigation water, and where this is not available shallow pools may be used. A fairly complete project of the application of this type of power plant has been worked out for the Touggourt oasis, which is of interest in that it demonstrates the conditions under which a power plant of this character may pay. The Touggourt oasis has a population of 12,000, and a flora comprising 350,000 palm trees. It was initially irrigated by 200 artesian wells, which in 1861 had an output of 1000 liters (265 gal.) per sec. The boring of new wells, however, has depressed the subsoil water level and made it necessary to go to much lower levels in order to obtain new sources of water, and even these have been gradually failing.

The project calls for a solar power plant with a mirror area of 2400 sq. m. (25,833 sq. ft.) giving an output of 100 kw. with an insolation of 7 cal. per sq. m. (10.764 sq. ft.). The power output per year will be 300,000 kw-hr., consumed as follows:

In the power plant itself	30,000
Lighting of villages	30,000
Small industries	20,000
Ice manufacture	10,000
Irrigation pumping	210,000
Total kilowatt-hours	300,000

It is estimated that the cost of construction will be 600,000 fr. ($42,000) of which 150,000 fr. ($10,500) will be for the mirror plant. The income and expenditures are estimated as follows:

Expenditures (in francs = 7 cents)		
General expenses		3,000
Personnel	Manager	15,000
	Electrician	9,000
	Four native workmen	7,000
Lubrication, waste, etc., 0.01 fr. per kw-hr.		3,000
Superheater service, 0.200 kg. (0.44 lb.) of coal per kw-hr.		20,000
Maintenance and repairs		20,000
Amortization at the rate of 6 per cent in 15 yr.		60,000
Interest, etc.		115,000
Total		252,000
Receipts		
Lighting, 30,000 kw-hr. at 1.50 fr.		45,000
Petty industries, 20,000 kw-hr. at 1.00 fr.		20,000
Ice, 100 tons at 200 fr.		20,000
Distilled water, 360 tons at 75 fr.		27,000
Irrigation pumping,[1] 200,000 kw-hr. at 0.70 fr.		140,000
Total		252,000

In the above plans no mention is made of the depreciation of the distribution system, the item "Interest" being sufficient to take care of this.

The item "Distilled water" corresponds to a daily consumption of 1000 liters (265 gal.) which is double the present consumption, but it is to be sold at a price of 0.075 fr. per liter as compared with the present price of 0.20 fr. Water from the wells contains too much magnesia salts to be fit for drinking. (*Génie Civil*, vol. 82, no. 14, Apr. 7, 1923, pp. 327–329, *d*)

Water-Tube Boiler Troubles

Constructional Defects in Water-Tube Boilers, R. Schirmer. This paper calls attention to the fact that of later there have been increasingly frequent reports of trouble with water-tube boilers, in particular ruptures of the boiler walls, and that the causes of these troubles are not yet as clear as they should be.

The author believes that many of these accidents have been due to the constantly increasing specific loads imposed on the boilers, as a result of which the boiler parts do not take up the heat supplied to them fast enough and distribute it uniformly enough, which brings about stresses in the material. To this kind of damage are particularly exposed boilers which have been at first operated at comparatively light loads and from which a much higher output had been demanded later. In some cases, in order to obtain this higher output larger grates have been installed in the expectation that the boiler would deliver the greater output as it had worked satisfactorily in the past. Of course this does not always happen.

H. Schonger, in a recent German publication, has called attention to the fact that cracks in boilers operating in central stations are particularly frequent in the header flanges and end plates of water-tube boilers. All conditions, however, go to show that it is not the defective manufacture of the parts but the circumstances of their operation that are the cause of trouble. It is pointed out particularly in this connection that such flange ruptures do not occur in other boiler systems or in old water-tube boilers, possibly because these latter have operated at only a fraction of their present specific loads. It would therefore appear that the accidents in boiler operation are due at least in part to the increasing loads which have been demanded from boilers since the introduction of the Stirling type of generator. There has been of late a sort of competition between the Stirling and the straight-tube types of boiler, each attempting to surpass the other either in specific output or in the reduction of space for a given output. The Stirling type is well adapted for this kind of competition, whereas the straight-tube boiler has been made to perform at the enhanced rate without a thorough alteration of its design, which is unfortunate, because a straight-tube boiler appears to be unsuited by its construction for the rapid equalization of thermal expansion of the parts. As a result there have been numerous breakages of parts which can be directly ascribed to stresses of thermal origin.

It is stated in the report of H. Schonger, referred to above, that the flange cracks reach their greatest depth at the lowest part of the end plate, and in extending toward the water line on both sides gradually lose in depth. The same thing has been observed on the lower drums of a large Stirling-type boiler. These drums, it may be stated, were in this instance made not of a single shell plate but of three rings.

Figs. 6 and 7 show these lower drums. All such boilers have two boiler drums connected by short curved tubes, the water circulating in the direction indicated by the arrows. It is usually

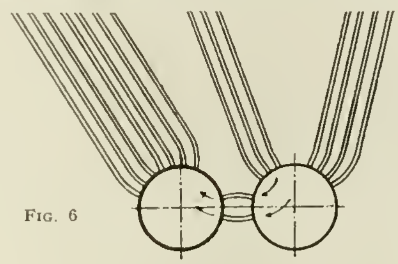

Fig. 6

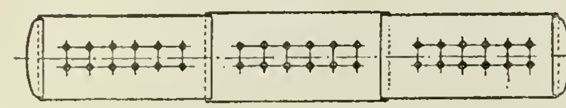

Fig. 7

Figs. 6 and 7 Construction of Lower Drums of a Boiler Where Leaks Due to Unequal Heating Appear

Fig. 8

Fig. 9

Fig. 8 Diagrammatic Representation of Distribution of Leaks in the Drums of Boiler Shown in Figs. 6 and 7.

Fig. 9 Diagrammatic Representation of Water Circulation in the Drums of Boiler shown in Figs. 6 and 7.

assumed that the total drum water content is free to circulate at a uniform rate and therefore that there are no dead spaces in the lower drum. While firing up this boiler, however, leaks appeared at the circular seams as soon as the temperature of the water in the upper drum approached the boiling point. When the steam pressure increased the water spurted through the seams in jets, the interesting part about it being that this occurred only on the lower part of the two lower drums, while the upper parts of the same drums have never shown any lack of watertightness. Moreover the leaks increased with the approach to the middle plane of the drums as shown diagrammatically in Fig. 9, but ceased entirely at the level of the lower connecting tube. No matter how slowly and carefully the boiler was heated up, it proved to be impossible to prevent these leaks, and even after the upper drum began to deliver steam, cold water could be obtained from the lower drum by opening the bottom cock. It was, however, possible to combat this source of trouble by letting off from time to time the water from the lower drums during the heating up of the boiler, this operation being repeated until the water in the lower drum attained a temperature corresponding to the steam pressure, whereupon the danger of leaks disappeared.

There is no doubt that these leaks are caused purely through thermal stresses, which in their turn are due to the imperfect water circulation in the lower drums.

As shown in Fig. 8, there forms in the lower drum a dead layer of cold water at the level below the interconnecting tubes, while the water above this dead layer circulates with the rest of the boiler water. This results in the fact that the upper part of the shell of the lower boiler is heated up faster than the lower part,

[1] Attention is called to the fact that in a previous paragraph the power consumption for irrigation pumping is estimated at 210,000 kw-hr. and no mention made of distilled-water production, possibly because the latter is merely a by-product.

and as the circular rivet seams are not strong enough to withstand the stresses created by this unequal expansion, leaks appear in the drum. It is only after all the cold water from the bottom of the lower drums has been drawn off through the cocks that the two parts of the shell become heated up uniformly and the irregular thermal expansions and consequent leaks disappear.

It is permissible to assume that the rupture of a welded seam in the lower drum in another large Stirling-type boiler may have been due to the same cause. In this case it is well to avoid the use of welded circular seams, or at least when using them to employ reinforcing straps.

From this the author proceeds to a discussion of straight-tube boiler troubles, which he believes may be likewise due to thermal stresses produced by unequal heating. In fact, he believes that the straight-tube boiler is exposed to this kind of trouble in an even greater degree than the Stirling type. Furthermore the lower half of the shell of the upper drum in the straight-tube boiler is exposed to additional stress due to the fact that the tube system expands to a greater degree than the boiler drum located above it. If, therefore, the circular seams of the upper drum lying between the collars of the headers are strong enough to take up these additional stresses, the flanges of the header covers or connecting expanders will be frequently overstressed to such an extent as to produce ruptures. These stresses applied initially to flanges are transmitted to the end plates with all the greater ease the nearer the latter are forced to the connector expanders. Furthermore, since the rear end plates are located closer to this critical connecting place the front end plates are more exposed to the successive stresses, which would explain the greater frequency of cracks and ruptures in these rear end plates.

It would be natural to expect that damage of this kind would occur with particular frequency in boilers which are fired up often rather than in boilers operating continuously. After a boiler has been operated for any length of time the heat throughout becomes equalized to such an extent that the stresses in the material disappear. In central-station practice the boilers have to be cut in and out with comparative frequency. Furthermore, when high peak loads have to be taken care of, extra boilers must be heated up quite frequently and rapidly. Conditions of boiler operation in central stations are therefore such as to be particularly favorable to the formation of cracks and ruptures. On the other hand, of course, boilers should be adapted to take care of conditions in central-station operation rather than that these latter should suffer in their adaptation to boiler limitations. Boilers should be so built that even when fired up in a hurry the heat will distribute itself throughout the boiler in as short a time as possible, not only uniformly but without the production of local stresses even when the load is varied with great rapidity. This requirement can be satisfied only by the establishment of a perfect water circulation of the entire water content, which is far from being the case with the present conventional construction of straight-tube boilers.

From this point of view greater advance has been made in Stirling-type boilers and of late there has been an increasing tendency to provide large connections to the upper drums, the only limit to this tendency lying in the strength of the boiler shell. Larger passages are also provided for the flow of steam between the upper drums.

At the same time it should not be forgotten that all connections between the upper drums may result in hindering the water circulation, as improper dimensioning of such connecting elements may lead to violent variations of the water level, priming, etc. It is because of these difficulties that there is still considerable distrust in many circles with respect to the Stirling-type boiler. (*Die Wärme*, vol. 46, no. 2, Jan. 12, 1923, pp. 15–18, 4 fig. *p*)

RAILROAD ENGINEERING (See also Machine Parts)

New 4000-Hp. Electric Locomotives for the N. & W. Railway, T. C. Wurtz. Description of the design of four locomotives recently ordered by the Norfolk & Western Railway, the particular points of interest being the design of the cab and drivers, and some of the electrical features.

The new unit will consist of two cabs permanently connected to form a locomotive. The equipment in each cab will be identical so that any two cabs can be coupled together back to back to form a locomotive unit.

The cab structure is not supported by springs and sliding bearings as formerly but is fastened rigidly to and is carried by side frames. These latter are massive vanadium-steel castings connected by cross-ties which are also used to support the heavier pieces of electrical apparatus mounted in the cab.

The four pairs of drivers on each cab are single-truck, the former practice having been to have two trucks on two pairs of drivers each connected by a Mallet hinge.

As regards the electrical features, the most interesting is the use of an oil-insulated force-cooled transformer. The oil-insulated type of transformer has been almost universally used in single-phase European electrifications, but up to this time the air-blast transformer was the standard in this country in all trunk-line installations. Cooling of the oil-insulated transformer is accomplished by means of pumping the oil through a force-ventilated radiator.

The service to be performed by these locomotives is unquestionably the most severe to which any electric locomotive has ever been subjected. The traffic consists of heavy-tonnage coal trains of 4200 tons hauled up six miles of 2 per cent grade on a road noted for its curves. The speed of the train up this heavy grade with two locomotives is 14 m.p.h. Acceleration of these heavy trains on a 2 per cent grade with reverse curves is part of the normal operation, and is accomplished with ease. The performance of this type of locomotive has been so remarkable that the operating officials of the railway are enthusiastic in their praise and more than satisfied with their operation, as shown by the recent order for four additional locomotives having 30 per cent greater capacity than those now in operation. (*Railway Review*, vol. 72, no. 15, Apr. 14, 1923, pp. 647–650, 4 figs., *d*)

REFRIGERATION

The Compression Refrigeration Cycle

The Compression Refrigerating Cycle, W. H. Motz. Paper based upon the results of the recent Bureau of Standards experiments on ammonia and what may be termed good operating practice. The author gives numerous interesting charts plotted for the first time from the Bureau of Standards tables and also from actual tests on a refrigerating machine. The paper is not generally suitable for abstracting, but attention may be called to the following.

In the original article a chart is given showing the values of the theoretical volumes of compressor piston displacements for the assumed conditions in the evaporator and condenser. (The amount of ammonia evaporated per minute per ton of refrigeration has been taken for standard conditions as 0.442 lb.)

As regards volumetric efficiencies of a compressor cylinder, they appear to depend generally on a large number of factors. However, in vertical single-acting compressors in which the clearance has been reduced to the minimum and in which valves of large area are used, the principal factor affecting the efficiency of the cylinder is that of the superheating of the vapor during the suction stroke. With respect to the volumetric efficiency due to the superheat of the vapor during the suction stroke, it is said that there are a number of factors which affect the relative magnitude of this efficiency. In consideration of this fact it is practically impossible to determine these efficiencies by mathematical analysis, and they can be determined only by actual tests on actual ammonia-compressor cylinders and should therefore be termed an operating characteristic of the compressor cylinder.

For the purpose of comparison and calculation in this paper the author has used tests made on actual ammonia-compressor cylinders for the purpose of determining the relative magnitude of the efficiency due to superheating. Data taken from the most authoritative tests were plotted on curves, from which, by means of extension and extrapolation, the values of the volumetric efficiencies for the assumed conditions were obtained. The values of the volumetric efficiencies due to superheating, as determined by this means for vertical single acting ammonia compressors, are shown in Fig. 10. These values are the volumetric efficiencies with a factor of safety of approximately 10 per cent. As previously

indicated, these may be termed volumetric efficiencies due to superheating, due to the fact that a very large proportion of the loss of efficiency is due to the superheating effect. The tests on the actual refrigerating machines were conducted by experts after all parts of the system had been put into as nearly perfect mechanical condition as possible, clearance reduced to the minimum, etc. Therefore the values of the volumetric efficiencies may be taken to present primarily the effect of superheating. It is well to

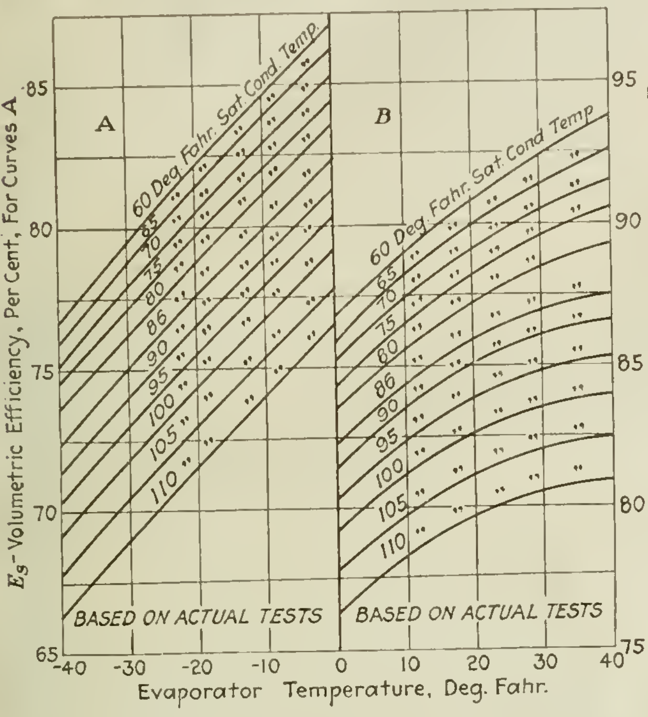

Fig. 10 Volumetric Efficiencies for Vertical Single-Acting Compressors

point out that it is possible to obtain volumetric efficiencies which are better than those shown by Fig. 10, but that these values may be assumed to represent good practice.

The author next discusses the effect of clearance upon the volumetric efficiency of a compressor cylinder, which may be determined mathematically if the amount of clearance is known, and gives a

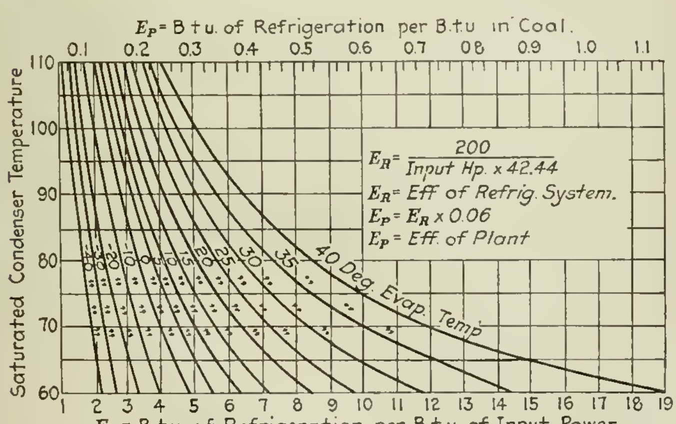

Fig. 11 Overall Efficiencies of Refrigerating Plants

chart showing the value of factors determining this clearance.

The thermodynamical expression for the volumetric efficiency due to clearance [the formula is given in the original article] involves the exponent n of the characteristic law of compression PV^n = constant. This exponent varies within certain limits as ammonia vapor is not a perfect gas, but the latest data from the Bureau of Standards on the properties of ammonia vapor seem to indicate that the average value of n may be taken to be 1.28, and the author uses this value both to express the volumetric efficiency due to clearance and to determine the total efficiency due to clearance. This latter, on the assumption that the clearance is 3 per cent of the cylinder volume, is found to be 92.56 per cent for a given case.

The true volumetric efficiency of the compressor cylinder is a function of the product of the volumetric efficiency due to superheating and that due to clearance. The mean effective pressure of ammonia in a compressor cylinder is also affected by the amount of clearance.

The second part of the article is devoted to the subject of power and water requirements, and is accompanied by interesting charts. Among other things, the author establishes in the form of an equation the relationship between the gallons of water required per minute, the heat removed in the condenser, and the temperature range of water, and gives a chart showing the relative amount of water required in gallons per minute per ton of refrigeration for rises of temperature of the water from 4 deg. to 20 deg. for certain assumed operating conditions.

The efficiency or coefficient of performance of refrigerating systems is next discussed and expressed in several ways. The general conclusion at which the author arrives is that the smaller the temperature range the better the performance. In other words, a smaller amount of energy is required to cool a substance a few degrees than is required to cool a part of it through several degrees, such as one-tenth of the substance through ten times as many degrees. For standard conditions the overall efficiency on performance is expressed as a formula. The ratio given may be termed B.t.u. of refrigeration per B.t.u. in the coal. In the original article such ratios of B.t.u. of refrigeration to B.t.u. in coal have been calculated for the assumed operating conditions and are shown in Fig. 11. (Paper presented at the Annual Meeting of The American Society of Refrigerating Engineers, December, 1922, abstracted through *Refrigerating Engineering*, vol. 9, no. 9, March, 1923, pp. 267–274 and 279–280, 12 figs., *pt*)

Composition, Purification, and Certain Constants of Ammonia, E. C. McKelvy and C. S. Taylor. In this paper methods for the testing of commercial ammonia are described and applied to eight standard American brands and three brands of German origin. The results of these analyses indicate that most commercial ammonias contain less than 0.1 per cent of impurities. Previous methods used for the preparation of pure samples are reviewed briefly. Apparatus used for fractional distillations at pressures greater and also less than atmospheric pressure are described.

Emphasis is placed upon the removal of non-condensing gases, and methods of removal and testing are described in detail, together with a method for opening sealed glass containers and testing the contents for non-condensing gases.

Five methods for the preparation of samples are described in detail and the physical measurements made upon each sample indicated. The different preparations are tabulated, together with the analyses and uses.

Ammonia has been prepared which contained, as far as any known test indicated, no organic impurities, less than 1 part in 1,000,000, by volume, of non-condensing gases, and less than 0.003 per cent, by weight, of water.

The following physical properties of pure ammonia were determined: The density of the solid, 0.817 gram per cu. cm. at —79 deg. cent. and 0.836 gram per cu. cm. at —185 deg. cent.; the freezing point, —77.70 deg. cent., and the vapor pressure at that temperature, 45.2 mm. of mercury. (*Scientific Paper of the Bureau of Standards*, no. 465, Mar. 9, 1923, pp. 655–693, 6 figs., *e*)

SPECIAL MACHINERY (See Engineering Materials)

SPECIAL PROCESSES (See Engineering Materials)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general, *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Proposed Code for Care of Power Boilers

Preliminary Report of Sub-Committee of A.S.M.E. Boiler Code Committee on Rules for Care of Steam Boilers and Other Pressure Vessels in Service

THIS Report of the Sub-Committee of the Boiler Code Committee on Code for the Care of Power Boilers is suggestive only and will be proposed for discussion at the Spring Meeting of the Society at Montreal, Que.

The work of this Sub-Committee of the A.S.M.E. Boiler Code Committee has been actively pushed forward during the past year and its report is here presented for public discussion. This report is intended to form a section of the A.S.M.E. Boiler Code, the Sub-Committee which was appointed in 1922 to consummate this work being as follows:

F. M. Gibson, *Chairman*	W. H. Larkin, Jr.
E. G. Bailey	J. S. Schumaker
W. G. Diman	H. F. Scott
J. R. Gill	N. Stahl
J. W. Hays	J. Wolff
S. F. Jeter	

It is the request of the Committee that these proposed rules be fully and freely discussed so that it may be possible for any one to suggest changes before the rules are brought to final form and presented to the Council for approval. Discussions should be mailed to C. W. Obert, Secretary of the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be considered by the Boiler Code Committee.

A.S.M.E. BOILER CODE

Report on Rules for Care of Steam Boilers in Service

POWER BOILERS

These Rules apply only to steam boilers constructed in compliance with Part I, Section 1, of the A.S.M.E. Boiler Code and for operation at a steam pressure exceeding 15 lb. per sq. in. above atmospheric pressure. These rules do not apply to boilers which are subject to federal inspection and control, including marine boilers, boilers of steam locomotives and other self-propelled railroad apparatus.

INDEX

RULES FOR THE PREVENTION OF DIRECT CAUSES OF BOILER FAILURES

OVERPRESSURE

Indicators

C-1. Steam Gages. Steam gages shall be placed where they will be free from vibration and where they can be conveniently adjusted. They shall be so placed that they will not be subjected to a temperature of less than 40 deg. fahr. or more than 150 deg. fahr. They shall be of such size and so proportioned and marked that the position of the pointer and the graduations can be clearly determined by a person with normal vision standing on the operating floor at any point within a radius of one and one-half times the width of the boiler setting measured from the center of the boiler front. Steam gages on all boilers, where set in battery, shall be practically the same in size and graduation of face.

C-2. Steam gages shall be well lighted at all times. When natural light is used the gage shall be so placed that the rays of light will not cause a reflection upon the glass cover thus obscuring the dial when viewed from the most desirable points of observation. When artificial light is used the light shall fall directly upon the face of the gage. Whatever form of light is used, no light shall fall directly into the eyes of the operators when looking at the gage from the most desirable points of observation.

C-3. Where steam gages are installed with waterleg, compensation shall be made in the gage to neutralize the effect of the water in the gage connections. Where steam gages are placed high above the operating floor, they shall be tilted forward at a sufficient angle (not to exceed 30 deg. with the vertical) to permit a proper view of the dial graduations.

C-4. Piping for steam gages shall be as short as practicable and shall be free from pockets and air traps. When the pipe line is longer than 10 ft., the pipe size shall not be less than $^3/_8$ in. standard pipe size.

C-5. A steam gage shall be considered tested when it has been compared and made to agree with a test gage or dead-weight testing device, unless compensation for waterleg has been made, in which case an equivalent allowance shall be made in the reading of the test gage or dead-weight testing device. The test gage shall be a reliable gage that is used exclusively for testing gages in service and one that is tested and maintained in agreement with a dead weight testing device.

C-6. Boiler gages shall be tested frequently, at times of external inspection, when boiler is placed in service, and when safety valve is operating and the pressure indicated by the steam gage is not in agreement with the pressure at which the safety valve is set to open.

C-7. A master gage is an auxiliary gage attached to the main header indicating the composite boiler pressure of the whole battery; it is used in the general operation of the plant mainly as a matter of convenience. Master gages shall be tested at least every three months and more frequently when trouble is experienced with boiler compounds, foaming, priming and other feedwater troubles that are apt to cause choking of the gage piping.

C-8. All steam gages shall be within two per cent of error in the range between the working pressure and the pressure of the opening of the safety valve.

C-9. Before a steam gage is tested, it shall be disconnected at the gage union while the piping, cock and siphon are being cleared

by blowing through. A tee with a plug shall be placed between the siphon and the gage for the purpose of connecting the test gage. Care shall be taken not to admit steam directly into the gage, making sure at all times that the siphon is filled with water. In opening the connection to the gage, the operator shall open the cock slowly while holding one hand on the siphon until the gage indicates full boiler pressure; if the temperature of the siphon indicates that steam instead of water is entering the gage, the cock shall be closed until a sufficient amount of water has accumulated in the piping.

C-10. When laying up a boiler, particularly in freezing temperatures, the gage connection shall be drained and the gage shall be disconnected and stored away in a non-freezing room.

C-11. The dial and glass cover of steam gages shall be kept clean at all times. The glass cover joint shall be tight and, whenever the glass is broken, it shall be replaced as soon as possible.

C-12. Water Glasses and Gage Cocks. The valves and connections between the boiler and water column shall be kept free and clear and shall be tested by blowing down the water column, noting the return of water in the glass, and trying the gage cocks until sure of the water. They shall be tested by the responsible operator on the relieving shift before the relieved shift has gone off duty, also after replacing or cleaning the water glass and when a boiler is put in service.

By *shift* is meant a person or group of persons who relieve a person or group of persons in rotation in standing watch or operating a steam generating plant for an allotted time. It is synonymous with watch, vigil, or tour of duty.

C-13. The water glasses and their connections shall be kept free from leaks and no alterations, allowing a flow of water from the piping between the water glass and the boiler, shall be made.

C-14. The outlet end of the discharge pipes from the water columns, water glasses and gage cocks shall be kept open and either in sight or in hearing of the operator while blowing down.

C-15. The water glasses shall be so lighted that the level of the water in the glass can be readily seen from the most desirable points of observation and the light shall be so shaded that it will not shine directly into the eyes of the operator when looking at the glass. The inner and outer surfaces of the water glass shall be kept free from deposits of dirt and the connections of the water glass shall be so arranged that the inner surface of the glass can be cleaned by forcing through the glass a piece of cloth, free from lint and dirt, wound about a smooth piece of wood. Types of gage glasses and guards which prevent the free observation of the glass shall not be used.

C-16. Where automatic alarms for indicating extreme low water level or extreme high water level are used, they shall at all times be kept in good working order but shall not be depended upon in maintaining a proper level of water in the glass. When an automatic alarm sounds and the level of the water is not visible in the glass, the operator shall test the try cocks to determine the water level before manipulating the feed water valves.

C-17. Fusible Plugs. Flusible plugs, if used, shall be kept in good condition and shall not be used for more than one year as provided for in Par. 428 of the Rules for the Construction of Power Boilers. When the boiler is open, the exposed surfaces of the fusible metal shall be scraped clean and bright and the surface of the boiler near the plugs shall be scraped clean. If the fusible metal does not appear sound, the plug shall be renewed. If used plugs are refilled, all of the old filling shall be removed, the surfaces of the shell scraped bright and properly tinned and the plug filled with pure tin as specified in Par. 428 of the Rules for the Construction of Power Boilers. Fusible plugs shall not be refilled with used metal.

Relief Equipment

C-18. Safety Valves. All safety valves shall be kept clean and in working order.

C-19. The capacity of safety valves shall be calculated, as provided for in Pars. 269–290 (inclusive) of the Rules for the Construction of Power Boilers, under the following conditions and if necessary a larger safety valve installed; when the allowable working pressure of a boiler has been reduced, when a boiler is equipped with increased stoker capacity or when a change in fuel permits increased combustion.

C-20. Whenever the stipulated blowing pressure of a safety valve is 10 per cent higher or lower than the pressure for which the spring of the valve is designed, the safety valve shall be equipped with a new spring complying with the requirements given in Pars. 269–290 (inclusive) of the Rules for the Construction of Power Boilers.

C-21. When a safety valve spring has weakened and has been further compressed to secure the stipulated blowing pressure, an examination of the spring shall be made in order to insure its compliance with the rules given in Pars. 281, 282 and 284 of the Rules for the Construction of Power Boilers.

C-22. Where boilers are set in battery and operating under the same working pressure and some of the boilers have allowable working pressures greater than others, all safety valves shall be set to blow off at a pressure not in excess of that allowed on the weakest boiler.

C-23. Safety valves shall be tested at least once a day by gently raising the valve off the seat by hand and, when practicable, shall be tested daily by raising the steam pressure to the blowing pressure of the safety valve. Small chains or wires attached to the levers of pop safety valves and extended over pulleys to other parts of the boiler room may be used.

C-24. When a safety valve sticks or fails to operate at the stipulated blowing pressure, no attempt shall be made to free it by striking the body or other parts of the valve but the boiler shall be taken out of service and the safety valve examined.

C-25. The safety valve, when blowing, shall be checked against the boiler gage and when the pressure noted on the boiler gage varies more than 5 lb. from the stipulated blowing pressure, the boiler gage shall be tested and if found correct, the safety valve shall be corrected.

C-26. The setting and adjusting of safety valves shall be done by a competent person. When safety valves are set or adjusted, the level of the water in the boiler shall not be above the highest gage cock.

C-27. In order to insure that the freedom of the spring is in compliance with the Rules given in Pars. 282 and 284 of the Rules for the Construction of Power Boilers, it shall be tested whenever the valve spring is adjusted.

C-28. After a hydrostatic test has been made, special care shall be taken to see that the safety valve is immediately restored to its proper operating condition.

C-29. Leaking safety valves shall be repaired or replaced as soon as discovered.

C-30. Care shall be exercised to prevent the accumulation of dirt, scale or other foreign matter between the coils of the spring.

C-31. The discharge from the open end of escape pipes shall be unobstructed and, if practicable, inside of the boiler house within hearing of the operator.

C-32. All supports and anchors that are attached to the escape pipe, shall be tested every six months and the proper tension maintained.

C-33. Escape pipe drains shall be examined monthly and the escape pipes shall be disconnected once a year in order that the drain may be kept free and clear at all times.

C-34. Intercommunicating Valves Between Systems of Different Pressure. Where intercommunicating systems of different steam pressures are installed with boilers on each system, the boilers on the low-pressure systems shall be equipped with non-return check valves. All low-pressure headers and their outlets shall be protected by a relief valve or valves whose combined capacity shall be equivalent to the total amount of steam that can pass from the higher-pressure system into the lower pressure system. Where a reducing valve is used, a hand valve shall be installed. Also a steam gage shall be installed at a convenient point for the guidance of a person when operating the hand valve in lieu of the reducing valve.

C-35. Whenever the total amount of steam that can pass from a higher-pressure system into a lower-pressure system has been increased, the relief-valve capacity shall be increased an equivalent amount in accordance with Par. C-34.

Feedwater Control

C-36. Pump Regulators. Feed-pump pressure regulators shall

be maintained in good condition and shall be frequently tested under closed discharge. When duplicate pump is not installed the pressure regulator shall be by-passed.

C-37. When feedwater pressure increases above normal, the feed lines shall be examined for possible choking due to scale or other causes.

C-38. Feedwater Regulators. Where feedwater regulators are used they shall be by-passed and shall be kept in good working condition, but shall not be depended upon to maintain a proper level of water in the boiler.

Excessive Combustion

C-39. Damper. Damper regulators and draft-control devices shall be kept in good working condition and shall be so installed that any failure of or accident to the mechanism of the damper will cause the damper to open and not to close.

C-40. Fuel Supply. Fuel-supply regulators shall be kept in good working condition and shall be so installed that any failure of or accident to the mechanism of the regulator will shut off the supply of fuel to the boiler and, once having shut off the supply of fuel, will not automatically resume the supply of fuel.

Operation

C-41. Manipulation of Valves. When cutting in a boiler, the stop valve shall be opened slowly to avoid water hammer and, where non-return check valve or stop and check valve is not installed, it shall be opened only when the pressure in the boiler is exactly the same as the pressure in the main boiler header. Where a non-return check valve or stop and check valve, as the case may be, is installed, it shall always be used automatically for cutting in and cutting out of the boilers; the main stop valve, in cutting in a boiler, shall be opened when the pressure on the boiler is still 10 or 15 lb. less than that on the main and, in cutting out the boiler, the main stop valve shall not be closed until after the non-return check valve has closed. Care shall be taken to drain the piping between the main stop and non-return check valves before cutting in the boiler.

WEAKENING OF STRUCTURE

Overheating

C-42. Lack of Water Supply. Special and constant care shall be exercised to maintain a proper and uniform water level in the water gage glass and to provide a continuous rather than intermittent supply of water to the boiler.

C-43. The water tender or any operator responsible for maintaining water in the boiler shall not permit any inattention, other duties or reliance upon automatic devices to interfere with the performance of his duty in preventing low water level in the boiler.

C-44. Where practicable, a duplicate source of supply of feedwater, pump or injector and piping systems to the boilers shall be installed. Where two systems of piping to the boilers are used, it is recommended that the two systems enter the boiler at different points. Feed pumps and injectors shall be maintained in good condition.

C-45. Leaks in the feed discharge line or elsewhere shall be stopped as soon as possible.

C-46. Sufficient water shall be maintained in feedwater tanks to prevent loss of suction in the feed pumps and, where hot water is fed to or allowed to splash in feedwater tanks, sufficient water shall be maintained in the tank to prevent entrainment of vapors.

C-47. Feed lines shall be free from objectionable vibration due to feed pump.

C-48. Where electrically driven feed pumps are used, there shall be maintained, ready for service, steam-driven feed pumps of sufficient capacity to safeguard the boilers in case of failure of electric power.

C-49. Restricted areas in feed lines, such as meter tubes, orifice plates, etc., shall have a by-pass equivalent in size to the pipe line.

C-50. Where economizers are installed in the feed line, they shall have a by-pass equivalent in size to pipe lines.

C-51. All feedwater tanks shall be cleaned out frequently to prevent the accumulation of objectionable sediment.

C-52. When feedwater tanks are installed, and the water level cannot be observed easily by the water tender, suitable water-glass or water-level indicators shall be installed.

C-53. Frequent inspections shall be made to detect scale and defective check valves in the feed line.

C-54. Feedwater regulators or other automatic devices shall be maintained in good working order.

C-55. If difficulty is experienced in maintaining the proper water level, the combustion shall be checked and the draft dampers and ashpit doors closed until the cause is discovered and corrected.

C-56. If the level of the water is not visible in the water glass, the gage cocks shall be tested to ascertain whether the level of the water is above or below the water glass. If the level is below the water glass, the supply of fuel and air shall be stopped and the dampers and ashpit doors closed. The feedwater valve shall be closed and under no circumstances shall any attempt be made to admit water to the boiler. The fire shall be hauled or in case of stokers or chain grates, the grates shall be kept in motion and the fire doors shall be left open. Water from fire or other hose shall not be thrown upon the fire. The safety valve shall not be opened, steam outlet valves shall not be changed nor shall any change be made that will cause a sudden change in the stresses acting upon the boiler. The blow-off valves shall be examined and, if found defective, repaired. The cause of the failure of water supply shall be determined and remedied.

C-57. Where both cock and valve are used in the blow-off line, the cock shall be placed between the valve and the boiler. All blow-off cocks and valves shall be kept free from leaks and in good working order.

C-58. Blow-off piping shall be extra heavy from boiler to valve or valves, and all fittings between the boiler and valves shall be of steel. Blow-off pipes shall be so located that all exposed portions within the building, and within any pipe tunnel, opening directly into the boiler room, can be inspected and such portions of the blow-off piping which occur within the boiler room, or within any pipe tunnel opening directly into the boiler room, shall be installed to withstand full working pressure of the boiler.

C-59. Blow-off valves shall be in such location that they are accessible, and if located in a trench or tunnel, an extension shall be applied to the valve stems so that they may be operated from the floor, or some convenient location.

C-60. In operating blow-off cocks and valves, they shall be opened and closed carefully and slowly; care shall be exercised to make sure that when the valves or cocks are closed, they are closed tight. Where both valve and cock are used in the same blow-off connection, the cock shall be opened before the valve and closed after the valve. In blowing off a boiler, the valve or cock shall be opened half way and remain so until one inch of water has been blown down and then the valve shall be fully opened and remain so until the blowing off is completed.

C-61. The amount of blowing off shall depend upon the amount of suspended matter in the feedwater, the number of hours per day that the boiler is in service and the rating at which the boiler is in operation; the minimum amount shall be one gage every twenty-four hours, except where the amount and frequency of blowing down is determined by chemical analysis. The blowing off shall be done when the boiler is operating at its lowest rating; a boiler shall be blown off as soon as it has been cut off the line and just before it is cut in.

C-62. When the operator is blowing down a boiler and cannot see the water glass, another operator shall be placed to watch the water glass and signal the operator blowing down the boiler.

C-63. The pipe and fittings between the blow-off valve and the boiler and their insulation shall be occasionally inspected in order to maintain them in good condition.

C-64. When practicable, the end of the blow-off line shall be visible in order to detect leakage.

C-65. Fouled Heating Surface. Boilers shall be kept free from scale, mud and sediment as far as possible at all times, particular care and attention being given to the heating surfaces, tubes and fire sheets.

C-66. Waters containing salt, magnesium chloride or nitrates should not be used in the boiler without outside treatment as they will cause pitting and foaming in the boiler.

C-67. Feedwaters should be made slightly alkaline with com-

mercial sodas or lime where free organic or mineral acids are present.

C-68. Feedwaters should be treated with commercial sodas where the impurities in 10,000 gallons of water are precipitated by one pound or more of carbonate of soda.

C-69. Where feedwaters contain 3 grains per gallon or more of carbonate of soda, or its equivalents in other sodas, the soda concentration within a boiler should not exceed 100 grains per gallon.

C-70. All feedwater should be passed through a heater before it is introduced into the boiler in order that any temporary hardness will be eliminated as far as possible and precipitated in the heater from which it can be removed easily.

C-71. Feedwater which is treated should be raised in temperature to a minimum of 180 deg. fahr., and the treatment should take place in an external vessel or heater separate from the boiler, which is suitable for receiving the precipitate formed by the elimination of the temporary hardness and the reaction of the chemicals thus obviating use of the boiler as a sludge tank as far as possible.

C-72. Commercial boiler compounds should not be used without intelligent supervision or without an exact understanding of their chemical composition, the exact nature of the scale-forming material in the water and the reaction which will be brought about by their combination.

C-73. Where water-softening apparatus is found necessary, operator should check by analysis, with frequency, the quantity of chemicals or other substances used in the softener against the scale-forming matter in the water.

C-74. Proper technical supervision should control the operation of any water softener.

C-75. Recommended procedure for treatment of boiler feedwater to obtain the best results and greatest assurance of safe operation is the daily sampling and analysis of feed and blow-down water, regulation of the blow down and prescription of feedwater treatment by some qualified chemical engineer at frequent intervals.

C-76. Where carbonate of soda or soda ash is used in the treatment of feedwater, it must be kept at a point below $^1/_2$ of 1 per cent normal alkaline strength or concentration to avoid pitting; that is about 15 grains per gallon, normal solution of sodium carbonate being 5.3 grams to 100 cc.

C-77. Graphite should be used with caution as a boiler-water treatment. It tends to choke up connections to draft regulators, steam gages, etc.

C-78. Kerosene should be used with caution in boiler as a scale remover. It is liable to leave behind inflammable gases, which have caused dangerous explosions in the past on the introduction of lights into the boilers, and it may distil into elements which will attack gaskets and joints of piping and fittings.

C-79. When soda ash is used to remove scale from boilers, it must be done under proper supervision, and when conditions are bad it is recommended that daily record be made of alkalinity and chloride content of the water in each boiler.

C-80. Where priming is experienced, a sample of trap discharge from steam main near boilers shall be tested for chloride and alkalinity frequently and the result recorded.

C-81. When scale is being removed from boilers by the treatment of feedwater, care must be used not to bring it down too fast as it may accumulate in piles and patches on the sheets over the fire causing bagging or blistering of the plates.

C-82. A piece of zinc should be hung in the interior of boilers which are subject to electrolytic action and a tendency to pitting. There should be a good electrical contact of low resistance between the boiler structure and the zinc, which must be fitted in a basket designed to prevent the danger of the disintegrated zinc from fall in a pile on the shell of the boiler or plugging tubes in the vicinity. Zinc should not be used where boiler compounds are being employed for treating feedwater.

C-83. Care shall be used to prevent the entrance of oil into a boiler, as it will collect in clots on the heating surfaces, causing bagging or rupture.

C-84. Where there is a possibility of oil in returns, feedwater heaters should be provided with oil filters. Entrainment return lines should be passed through some suitable filter bed such as excelsior, exhaust mains should be dripped and the oil separated out.

C-85. Discharge from heaters or heater coils for fuel-oil installations shall be wasted or diverted to other uses to prevent any oil reaching the boilers.

C-86. When boilers are taken off the line for cleaning and washing, they should not be blown down and opened before the brickwork of the setting has cooled, otherwise the scale will be baked hard on the metal surfaces making its removal difficult.

C-87. Boilers should be blown down at regular intervals under the supervision of some competent person for the removal of mud which has precipitated because of the elimination of temporary hardness in the water by heat, removal of scale-forming elements by treatment, and the ordinary settling down of impurities in general.

C-88. It is recommended that a feed trough be used with water-tube boilers which have longitudinal upper drums into which the feed line is connected, for the purpose of catching and facilitating removal of mud deposited from the temporary hardness in the water.

C-89. Boilers should be taken off the line at such regular intervals, especially where the water is being treated, blown down, opened and given a thorough washing, as to clear all tubes and heating surfaces of mud, slime and loose deposits.

C-90. Boiler tubes should be turbined as required, to free tubes from scale but with proper feed treatment and control very little turbining should be necessary. Removal of scale from the exterior of fire tubes by vibrating them with internal cleaner or hammer must be practiced with caution as it is a serious strain on thin tubes.

C-91. Boilers shall be provided with the necessary manholes and handholes so that all areas can be reached, lighted, inspected and washed with facility.

C-92. Soot should be removed from heating surfaces frequently. In addition to the use of mechanical soot blowers, the front tubes of many water-tube boilers should be blown and cleaned over the fire with a hand-operated steam or air lance.

C-93. The engineer in charge should make inspections of the internal and external surfaces of the boiler at frequent intervals, logging the result of such inspections in detail to form a basis of comparison from time to time.

C-94. Excessive Combustion. Care shall be used that there is no weakening of the boiler structure due to fire cracks, crystallization of parts, etc., because of an increase in the rate of operation, where stokers are substituted for hand firing, or there has been a change from low- to high-grade fuel, etc.

C-95. Furnaces shall be guarded against leakage of cold air which striking against hot surfaces of the boiler cause dangerous stresses.

C-96. In case of stokers and oil fires care shall be used to keep furnace temperatures down to safe limits and to see that only the best available refractories are used.

C-97. Oil flames shall not be allowed to impinge on side walls or arches as they will cause excessive spalling and endanger safety of the structure. Air pressure in the furnace shall not be allowed as it will force hot gases out through any crevices in the setting and tend to destroy it.

C-98. Secondary Combustion and Flaming Through. Where possible, the combustion chamber and the gas passages with their connections shall be constructed without blind pockets or spaces where unburned gas can accumulate; where such pockets or spaces are unavoidable, they shall be properly ventilated.

C-99. Where waste gases are used as fuel, they shall be by-passed to the chimney.

C-100. Before lighting a fire, the combustion chamber and gas passages shall be thoroughly ventilated. After the ventilation (in a gas-, oil- or pulverized-fuel-fired boiler) a torch or other flame shall be placed in the combustion chamber before the supply of fuel is admitted. If a torch is used the operator shall stand clear of the opening. In oil-, gas- or pulverized-fuel-fired boilers, a torch shall be used to light all burners until the brickwork becomes intensely hot and even then when all burners are out.

C-101. In the event of flare back or the snapping out of burners, the fuel supply shall be shut off and the boiler thoroughly ventilated before the fire is again lighted.

C-102. Secondary combustion shall be prevented by admitting sufficient air at all times to guarantee the complete combustion of the fuel before the gas has traveled one-half of the distance from

the fire bed or burners to the exit of the setting. Care shall be exercised to prevent the leakage of air into the latter passes and thus burning the gases in the latter passes.

C-103. When a fire is banked, the admission of air below the fire shall be checked and only sufficient air admitted to the combustion chamber above the level of the fire bed to prevent the accumulation of gases of imperfect combustion. The damper in the uptake shall be left slightly open or perforated to insure a slight draft.

C-104. In shutting down a boiler, the air supply shall be maintained until after the fuel supply is discontinued and in the case of oil-fired boilers until any oil on the floor of the combustion chamber is consumed. After all combustion has ceased, the air supply shall be continued only until the combustion chamber and gas passes are thoroughly ventilated.

C-105. Localized and Uneven Heating. Ample time shall be allowed for raising steam pressure to prevent uneven heating of the boiler and setting, especially where circulation of water may be sluggish, as in internally fired types; also on new installations where uneven expansion might effect the brickwork.

C-106. The surfaces in the steam space of drums shall not be exposed to the direct heat of the combustion chamber, or to the direct products of combustion. Baffles and brickwork shall be kept in repair at all times to prevent surfaces in the steam space of drums from becoming exposed to the direct heat of the combustion chamber.

C-107. When superheaters are a part of the boiler, some means shall be taken, when firing up, to blank off the direct affect of the hot gases by a damper, unless superheater is flooded or unless they are of a type protected to withstand the heat.

C-108. Cast-iron or wrought-iron sleeves of ample size shall be provided wherever pipes pass through the brickwork, to provide for expansion and contraction.

C-109. Rivet heads shall not be exposed directly to the heat of the combustion chamber, except where they are within the water space.

C-110. Boilers shall not be emptied until brickwork cools, as uneven expansion may take place.

C-111. Damper Regulation. Each boiler shall be provided with a draft gage and a recording temperature device in the stack used in connection with each battery. Every boiler shall be provided with a back damper which can be operated and adjusted conveniently from the firing floor by the fireman on watch.

C-112. Smoke flues from batteries of boilers shall be baffled in such a way as to equalize the draft between the boilers.

C-113. Where draft-control systems are used they shall not be considered as relieving the fireman of responsibility. He shall be alert at all times to detect unusual conditions which may cause excessive combustion and affect the safety of the structure.

C-114. Where electric devices are used to actuate draft-control apparatus, the operator shall use care to see that the current does not fail and to handle the situation promptly in case of failure of the electrical supply.

C-115. Should the damper connection break, the mechanism shall be arranged so that the damper will open automatically and the fuel supply shut off automatically.

C-116. Damper regulators, where used, shall be preferably of the so-called "dead beat" type with valve lever so arranged that after pilot valve has been opened by a slight shifting of the pressure-actuated lever, it will be returned to closed position by the movement of the piston rod which handles the damper, thus causing gradual changes in the draft condition.

C-117. Damper regulators and draft-control apparatus shall maintain the steam pressure within a total range of not more than 5 lb. for boilers carrying under 150 lb. gage pressure, and within 10 lb. for boilers carrying higher pressure.

C-118. In the case of oil-burning or powdered-coal furnaces, the back damper shall be opened wide when the fire is to be lighted.

C-119. Insulation. Blow-off pipes shall be protected from the products of combustion by firebrick or other heat-resisting material so arranged that the pipe may be inspected.

C-120. Structures supporting the boiler, or structures which are a part of the building, shall be protected from the heat of the combustion space by insulating material, or air space, and shall not be subjected to temperatures above 600 deg. fahr., which might affect the strength of the material, and cause strains to occur due to expansion. This applies particularly to structures located between the settings of boilers in a battery.

C-121. With the suspended settings the steel work shall be so designed and be of sufficient strength and rigidity to eliminate any strain on the brickwork, under conditions of temperature which might cause the steel to expand or contract.

C-122. Firebrick linings shall be set in such a manner that when heated the expansion will not affect the outside walls.

Internal Corrosion

C-123. General. The interior of all parts of boilers shall be examined frequently and watched continually for evidences of corrosion in the shape of grooving, pitting, wasting away or thinning of metal.

C-124. Upon the observation of any indications of corrosion, steps shall be taken promptly to counteract the condition. In case of steaming boilers, clear water or grayish color in the gage glass may be an indicator of safe water, while reddish or blackish colored water may be an indicator of corrosion in the boiler or its connections.

C-125. Boiler operators shall watch their raw-feed supply to guard against the possibility of corrosive elements becoming mixed with the water.

C-126. The presence of air and oxygen may be detected by warming a sample of boiler feedwater in a glass flask and noting the bubbles which collect.

C-127. Feedwater shall be examined from time to time for organic matter both by filtering and by testing with pure sulphuric acid which, when added to a sample of the water in test tube, will turn it brown should organic material be present.

C-128. Chlorides which are particularly active agents of corrosion shall be tested for by the addition of silver nitrate to a sample of water which contains a little potassium chromate indicator which gives a brownish red color in presence of chlorides.

C-129. A test for acidity shall be made often, particularly if the source of supply of feedwater is a river or pond in a manufacturing district. This test can be made by taking a sample of raw water, adding a drop of methyl orange which will turn the sample yellow if it is alkaline and pink if acid and corrosive.

C-130. Where complete water analyses are available, it is recommended that they be checked by Stabler's corrosion formula which classifies them in accordance with their acid-forming tendencies. Stabler's coefficient of corrosion is

$$C = H + 0.116\ Al + 0.0361\ Fe + 0.0828\ Mg + 0.0336\ CO_3 + 0.0165\ HCO_3$$

where the CO_3 term represents the carbonates, the HCO_3 the bicarbonates, and all the terms are expressed in parts per million. Where $C + 0.0503$ (calcium ion) = negative quantity, there will be no corrosion due to acidity. Where C is negative but $C + 0.0503\ Ca$ is positive, corrosion may or may not occur, the probability varying directly with the value of expression $C + 0.0503\ Ca$.

C-131. Water shall be kept slightly alkaline when there is reason to expect acidity, and possible corrosion. This maximum alkaline strength should not exceed one-half of one per cent normal (about 15 grains per U.S. gallon) unless under the direction of an expert feedwater chemist or engineer. Normal alkaline strength is 5.3 grams of soda ash or sodium carbonate to 100 cc. of distilled water.

C-132. The percentage of normal-strength alkalinity shall be ascertained with frequency and checked by the formula:

$$P = \frac{Qn}{S}$$

where

P = per cent normal strength
Q = number cc. from testing burette
n = percentage of normal strength of acid used in testing burette
S = number cc. in sample of water being tested.

C-133. This test for alkalinity shall be made by titration using

$\frac{N}{5}H_2SO_4$ (i.e., one-fifth normal sulphuric acid) in burette and phenol-pthalein indicator which changes from pink to clear water at the end point. Tests made for the detection of possible tendencies to corrosion must be made not only on the raw water but especially on the blow down water of the boiler.

C-134. Feedwater. Air and gases like oxygen, carbon dioxide and sulphur dioxide either in solution or mechanically mixed with feedwater are corrosive agents. Such feedwater should be passed through an open heater which has a top breather pipe to the air through which the gas may escape.

C-135. Where considerable trouble is experienced from air, oxygen and carbon dioxide in feedwater, some form of deactivator should be used. Closed heaters should not be used where air and gas is encountered in feedwaters as they tend to collect the gas, are corroded rapidly, and are dangerous for that reason.

C-136. Where air and gas are carried into the boiler they tend to lodge below the water line in the form of bubbles which make pits in the metal. In such cases the feed shall be treated with lime or caustic soda to make the water slightly alkaline (see preceding paragraph on safe limit), the water should be fed above the water line in the form of a spray and in extreme cases a vacuum pump attached to the open heater to clear it of air and gas.

C-137. All feedwaters which have magnesium compounds in them must be regarded with suspicion. Magnesium chloride under the action of heat decomposes and gives off hydrochloric acid. Magnesium sulphate, if salt is present, will produce hydrochloric acid under the action of heat. Such waters should be treated with carbonate of soda.

C-138. Feedwaters which contain sea water will cause corrosion and should be treated with sodium carbonate.

C-139. Boiler waters which contain calcium sulphate and organic matter shall be taken care of as they will produce sulphuric acid, a dangerous corrosive agent.

C-140. Calcium sulphate scale shall be removed from boilers promptly as it will decompose into sulphur dioxide and oxygen under the action of heat. This free oxygen attacks the metal of the boiler corroding it rapidly.

C-141. All nitrates are corrosive agents, and where they occur shall be neutralized by treating the feedwater.

C-142. Ammonium carbonates which come from barn and outhouse drainage are a source of danger which must be guarded against as they are very corrosive.

C-143. Acids in general must not be allowed to get into feedwater supply. Rivers which flow past manufacturing towns frequently pick them up; they may come from the decomposition of fats, vegetable oils and greases which were compounded into lubricating oils used in the plant; water from swamps and bogs may contain humic acid, tannic acid and carbonic acid; some patented boiler compounds contain free acids like tannic acid; coal-region water contains sulphurous acid, etc.—all are corrosive and their possible presence should be checked regularly by means of the acid test described in the preceding paragraph.

C-144. Pure water and distilled water shall be used with caution as boiler feed. The pure water has a marked capacity for dissolving iron. Distilled water always has an equal volume of CO_2 in it. Both are corrosive and should be made alkaline with lime or soda.

C-145. Rain water, especially where it comes from roofs of buildings near manufacturing centers, will contain more or less soot, salt and sulphur dioxide, all of which are corrosive agents which shall be guarded against.

C-146. Where coagulants are used, especially alum (sulphate of aluminum) decomposition may take place from the heat of the boiler, which sets free sulphuric acid, a dangerous corrosive agent.

C-147. Stray electric currents are possible in power houses, giving rise to obscure electrolytic reactions in the boilers which will cause pitting of boiler metal. For this reason boilers shall be grounded thoroughly.

C-148. Electrolytic action should be avoided as far as possible by the insulation of copper and brass pipes from the boiler structure, by the use of iron rather than brass or copper ferrules at tube ends when needed, by avoiding contact of dissimilar metals in the boiler structure, and by using care in keeping coal, cinder, scale, chips of copper, brass and lead out of the boiler.

C-149. Mill scale from tubes and shell plates shall be removed from boilers as it tends to promote electrolytic action and corrosion, especially where salt is present.

C-150. Defective circulation and unequal strains on members of the boiler structure tend to promote corrosion and must be checked where trouble is experienced.

C-151. Where pitting is experienced, the surface of the metal shall be cleaned carefully, the pits filled with zinc oxide paste to decrease the possibility of gas lodging in their cavities and to check the corrosive action. Where slight grooving and thinning have occurred the boiler drum shall be given an inside coat of portland cement or zinc paint.

C-152. Boiler Out of Service. When boilers are taken out of service for any length of time care shall be used to prevent corrosion. If they are to be left empty, they shall be oiled down as they are emptied, dried out with the help of a hot-air stove, have suitable amount of quicklime placed on boards in the interior and finally be closed tightly.

C-153. Boilers shall, if idle for considerable periods, be opened up each three months for examination and the renewal of the quicklime.

C-154. If idle boilers are to be left with water in them, this water shall be made slightly alkaline and the boiler pumped full of water. This water shall be heated to a moderate temperature for a short time to eliminate all the air possible. The boiler shall then be closed tightly, allowed to cool and shall be kept cold. In such cases a piece of bright, clean iron shall be hung in the closed boiler in such a way that it can be removed and inspected for rust and corrosion at regular intervals.

C-155. Where boilers are idle long periods filled with water, great care shall be used to keep this water cold as the maximum amount of corrosion is promoted by lukewarm water. For this reason feed valves and all steam connections shall be tight at all times.

External Corrosion

C-156. Leaks, etc. Boilers in service are always exposed to external leaks of different kinds which tend to corrode the shell. The operator shall guard against leaky safety valves and steam mains which drip on the boiler and cause external corrosion, especially where the water runs under protective coverings.

C-157. Leaky manholes and handholes particularly where ash and soot can collect are especially dangerous as they corrode the shell rapidly. Such places shall be kept clean and tight.

C-158. Boiler operators shall keep under observation at all times the blow-off pipe nipple that screws into the mud drum. Corrosion is especially liable to weaken the pipe at this point causing possibility of serious accident.

C-159. The roof over boilers shall be maintained in good condition as roof water leaking down on settings tends to destroy them as well as to corrode the boiler itself.

C-160. Quenching water shall not be played on hot ash and cinder in boiler pits as there is danger of wet ash being carried up on to the shell and tubes of the boiler causing corrosion.

C-161. Care shall be taken to see that ashes do not come in contact with the boiler at any point.

C-162. Leaky tubes shall be rolled or replaced promptly to avoid possible corrosion of the tube sheet.

C-163. Boiler out of Service. When the boiler is taken out of service it shall be cleaned externally and inspected for wet ash and soot.

C-164. When boiler is to be out of service for a long period it shall be given a coat of red lead, black japan, or tar paint to prevent external corrosion. The damper shall be closed and lime placed on several points in the setting to dry the air as much as possible. All openings into the setting shall be closed.

C-165. Where boiler has been taken off the line for an idle period, it shall be made certain that all feed and steam valves are shut and do not leak.

Erosion

C-166. Soot blowers shall be supplied with practically dry

steam: they shall be well drained before using. Care shall be taken to prevent too direct an impingement with a steam jet upon the tubes and tube sheets.

C-167. In using a steam lance, care shall be taken not to blow with too much force or for too long a period upon any one point, particularly about the lower end of vertical water tubes.

Stresses Other Than Internal Pressure

C-168. Boiler Supports. Foundations for steam boilers must be of ample size to carry the load, and where large concentrated loads fall within a small area of the foundation, as in the vertical types of boilers, the foundations should be reinforced and spread to prevent any settling which might throw the boiler out of line. When the boilers are set in a battery, and when the foundations are not tied together by reinforcement, the joints in connecting pipes shall be broken open occasionally to see that no strains have been placed upon the piping on account of settling of any of the boiler foundations.

C-169. Foundations and structures supporting a steam boiler shall be built to withstand any strain which may be transmitted to them by expansion or contraction of boiler or supports, and shall be tied together in such a manner as to maintain their proper relation.

C-170. Vertical fire-tube or water-tube boilers whose bases cover a small area shall be carefully shimmed to distribute the load equally at all points. All shims shall be of steel or iron and properly secured or grouted.

C-171. Steel structures supporting boilers shall be carefully protected from water from roofs or steam leaks, and wood or inflammable material shall never be stored close to supporting structures.

C-172. Supports for water-tube boilers shall be so designed that unequal strain shall not be brought upon the tubes by expansion or contraction. Structures surrounding the boiler shall provide for any expansion which may take place and eliminate any possibility of straining the tubes or injuring the boiler setting.

C-173. On suspended type of settings care shall be taken at all times to see that the load is properly distributed over all points of suspension.

C-174. Pipe-Line Supports. Pipe lines connected to boiler shall be installed with provision for expansion and contraction, and expansion bends shall be used where possible. Pipe lines shall be braced to prevent strains on boiler or connecting pipe lines, and supports shall be of sufficient strength and designed to withstand strains set up by possible water hammer or vibration.

C-175. Pipe-line supports shall not be attached to temporary structures which might be removed, or to wooden structures which might be injured by fire. Supports for piping shall not be attached to wooden or steel structures such as floor or roof beams, which might be deflected by changes in load.

C-176. Supports of Equipment or Other Structures. When stacks are supported from structures directly above the boilers, or from the boilers themselves, care shall be taken to protect all steel work from corrosion caused by water at this location running down on the stack, or from the roof.

C-177. Shafting and belting shall not be located over the boiler in such a position as to cause injury to the pipe lines, or cause strains on the boiler if an accident should occur to the belt, or the line of shafting. Supports for shafting shall be of sufficient rigidity, or, if necessary, separate structures should be provided the shafting to prevent vibration being carried to pipe lines, or to the boiler.

C-178. Safety-Valve Escape-Pipe Supports. To prevent injury to the boiler and setting, if necessary a safety-valve escape pipe shall be installed to carry the discharge or any condensation away. Escape pipes should be supported to prevent any strain upon the safety valve.

C-179. Supporting Columns Between Settings. Where supporting columns between settings, or near boilers, are exposed to corrosion, they shall be set on concrete piers at least one foot above the floor level, or shall be encased in concrete at least 2 in. thick, to a point above which corrosion will not occur. Supporting columns not protected by concrete against corrosion shall be exposed so that they can be thoroughly inspected, and shall be kept well painted.

C-180. All structures over boilers, whether they are part of the boiler installation or building structures, shall be inspected regularly to see that corrosion does not occur, and shall be kept well painted at all times.

C-181. Supports of Blow-off Lines. Blow-off pipes shall be supported and anchored to prevent strain being put on the boiler structure on account of expansion or contraction.

Molecular Changes

C-182. Crystallization is caused by alternate heating and cooling of the boiler metal and can be minimized by avoiding frequent and sudden changes of temperature.

C-183. Embrittlement may be caused by too high concentration of soda in the boiler water and can be avoided by maintaining a concentration of less than one-half of one per cent normal alkalinity.

Mechanical Injuries

C-184. All boilers, with their auxiliaries and appurtenances shall be located, as far as practical, where they will be least liable to damage from external forces such as building failures, flywheel explosions, flood, fire or explosions from the storage of inflammable material, belt transmission failures, etc.

C-185. Tube Cleaning or Scaling. Power, for operating mechanical hammers and cleaners used in removing scale or slag, shall be generated outside of the boilers being cleaned. When such tools are actuated by air, steam or water, they shall be operated at the lowest pressure sufficient to accomplish the work when the motion of these tools, actuated by hot water or steam, is generated within the tube, care shall be taken not to heat the tube to the extent of causing undue strains by expansion. Mechanical hammers and cleaners shall not be operated for more than a few seconds at a time at any one spot.

C-186. Loose Connections. The fastenings of all interior fittings such as braces, baffles, feed troughs, gratings, zinc baskets, dry pipes, etc., shall be maintained secure and free from lost motion.

C-187. Repairs. All repairs and replacements shall be subject to the rules for similar material and workmanship as given in the Rules for the Construction of Power Boilers.

C-188. No repairs, other than those of a routine character, shall be made upon a boiler except upon and in accordance with the advice of authorized boiler inspectors as required in Par. 409 of the Rules for the Construction of Power Boilers.

C-189. All repairs shall be made as soon as possible and a record of all repairs upon boilers and upon any equipment or auxiliaries affecting the safety of the boiler shall be kept. A record of all repairs deferred shall be kept with the reasons for their delay.

C-190. All leaks, however small, shall be traced to their source and the proper remedy, not only to stop the leak but to prevent its recurrence, shall be applied at once.

C-191. No repairs shall be made upon a boiler or upon any of its equipment while it is under pressure.

C-192. The shell or drum of a boiler in which a typical "lap-seam crack" is discovered along a longitudinal riveted joint for either butt-seam or lap joints shall be permanently discontinued for use under steam pressure. By "lap-seam crack" is meant the typical crack frequently found in lap seams extending parallel to the longitudinal joint and located either between or adjacent to rivet holes.

C-193. Cracks caused by flexure of the metal shall be repaired by removing the part affected and replacing it with a new part. The new part shall be of greater strength than the defective part or other means shall be employed to prevent a recurrence of the trouble.

C-194. Where corrosion becomes dangerous or when cracks appear, the boiler shall be kept out of service until the affected parts have been repaired or replaced. No welding or patching shall be done except upon and in accordance with the advice of authorized boiler inspectors.

C-195. Where pits occur closely grouped or aligned and are deep enough to affect the strength of the material, the affected area shall be removed and replaced by a hard patch. Isolated pits, not affecting the strength of material, shall be prevented from becoming serious by cleaning the pit to bare metal, washing with strong alkaline solution and filling with zinc oxide.

C-196. Leaking rivets shall be calked about the edge of the head and, if the leak continues, the rivet shall be removed and a new rivet put in. In removing the rivet, the center of the head shall be removed with a cape chisel, the remaining portions of the head driven inward and the rivet driven out by punch and hammer. If the rivet cannot be removed except by heavy hammering, the rivet shall be drilled two-thirds of the way through its body with a drill $^1/_8$ in. smaller in diameter than the rivet and the remainder of the rivet backed out. Before driving a new rivet, the rivet hole shall be made clean and free from burrs and sharp edges.

C-197. No attempts shall be made to make a joint tight by putting undue stress on the bolts. If a joint cannot be made tight without stretching the bolts, the joint shall be opened and the cause of the poor joint determined and removed.

C-198. Increasing the leverage of a wrench by a piece of pipe or other means shall not be permitted as an average man with a

12 in. wrench will stretch a $^5/_8$-in. bolt
18 in. wrench will stretch a $^3/_4$-in. bolt
24 in. wrench will stretch a $^7/_8$-in. bolt
30 in. wrench will stretch a 1 -in. bolt

This represents the limit which bolts should be expected to stand.

C-199. In cleaning gaskets from finished surfaces care shall be taken not to score or cut the surface.

C-200. When water tubes are sufficiently warped to prevent proper inspection for soundness and cleanliness, no attempt shall be made to straighten them in place; such tubes shall be renewed.

C-201. A water tube with a series of bags closely connected shall be replaced. Bags on water tubes shall not be set back. When the bag leaks or is abrupt with a tendency to pod or point to such an extent that there is an appreciable stretching of the metal or that there is a possibility of scale or deposit collecting in the bag, the tube shall be removed.

C-202. Tubes, which have been rolled until the thickness of the metal has been considerably reduced or until the life of the metal is probably destroyed, shall be renewed.

C-203. Tubes in fire-tube boilers, which have been rolled several times and still leak, may be improved temporarily by rolling and beading the tube and then inserting a tight-fitting ferrule of tube stock of a gage equivalent to that of the tube and of a length equal to three times the thickness of the tube sheet. The inner end of the ferrule shall be chamfered on the inner edge and the outer end shall be rolled and beaded after the ferrule is in place. When a ferrule is installed immediate steps shall be taken to replace the tube. There shall not be more than 10 per cent of the number of tubes in the boiler so equipped and not more than two adjacent tubes at any one time.

C-204. Tubes shall not be reënded or pieced by autogenous welding.

C-205. In removing tubes exceptional care shall be taken not to injure the metal around the tube hole. A tube in being removed shall be cut with a flat chisel from the end to the header or drum at two places about $^3/_4$ in. apart and the strip, between the cuts, raised from its seat and bent inward with a bar. The tube shall then be split through and beyond its seat with a tool as wide as the strip and ground to the curvature of the tube hole. A crumpling tool shall then be used to break in the end of the tube.

C-206. When a new tube is to be installed, the surfaces of the metal about the tube hole shall be made free from any projections due to mutilation and shall be thoroughly cleaned of scale or foreign matter. Any grooves, scorings or holes in these surfaces shall, if slight, be filled with iron cement or zinc oxide paste or, if of any magnitude, be built up by welding. The ends of the new tube, where they come in contact with the tube sheet or header, shall be made clean and smooth before the tube is put in place.

C-207. The expanding of the tubes shall be done by a competent person. Before expanding a tube, the expander shall be examined to see that it is equipped with the proper rollers, straight or tapered in the proper direction. Rolling shall be stopped when the rollers operate evenly all around the tube with sufficient pressure on the mandrel. The beading of a tube shall be done by rollers especially designed for the purpose or by a tapered mandrel driven into the end of the tube. The flaring, beading and welding of tubes and nipples and the amount of projection of the end of the tube beyond the tube sheet or header shall be in accordance with the rules given in Pars. 250, 251 and 252 of the Rules for the Construction of Power Boilers. The tube ends should be lightly rolled after beading.

C-208. The rules applying to the care of tubes and the surfaces about the tube holes are equally applicable to the care of the nipples and the surfaces about the nipple holes.

C-209. In removing slag from the exterior surfaces of a boiler or its tubes, care shall be exercised not to injure the metal.

RULES FOR INSPECTIONS

C-210. All power boilers shall be given one internal and two external inspections per year by the state or municipal inspectors having jurisdiction or by the inspectors of the insurance company carrying the risk. These inspectors are hereinafter termed authorized inspectors.

C-211. Similar inspections shall be made by the person responsible for the boiler plant as a whole who is hereinafter termed the plant inspector. Such inspections shall be supplementary to and in no wise considered as supplanting or superseding the inspections made by authorized inspectors. Such inspections shall be made in accordance with the following rules.

C-212. Between periodical inspections by authorized inspectors, the plant inspector shall closely observe the operation and condition of the boilers and shall report immediately to the proper authorities any serious defects, doubtful conditions or unusual occurrences.

C-213. An external inspection shall comprehend the superficial examination of the boiler, its appurtenances and connections and does not necessarily require that the boiler be off the line. It is a form of examination to check up care and management mainly.

C-214. The internal inspection of the boiler shall be a comprehensive and thorough examination in every detail, embracing particularly the determination of the suitability of the boiler for load and pressure carried, strength of its parts, possible deterioration in service, and advisability of its continuance under the pressure carried previously to inspection.

C-215. No particular preparations shall be necessary for an external inspection other than giving the plant inspector convenient access to the boiler and its connections.

C-216. The internal inspection shall call for somewhat extensive preparation, mainly the proper cooling and opening up the boiler together with a thorough cleaning of the boiler, including setting.

C-217. The cooling of boiler shall be done cautiously so as not to put undue stress on the heated surfaces and setting. The damper shall be opened wide and the ashpit doors opened allowing circulation of air in the usual way. The fire doors shall remain closed until boiler is cooled.

C-218. During the cooling process the large doors in the boiler front shall be kept closed in order to prevent rapid cooling of tube ends.

C-219. After the furnace and lining have become well cooled the fire doors may be opened as well as the clean-out door at the rear preparatory to sweeping out the accumulated ash and soot.

C-220. The walls, baffles, tubes and shell shall be thoroughly swept down and the ash and soot removed to give the plant inspector opportunity to examine the parts closely and to eliminate danger from hot contact.

C-221. The tubes shall be well dusted and cleaned with steam soot blowers before the cooling operation has commenced. Steam shall not be used to clean tubes of a cold boiler as the moisture cements the soot and ash into a hard mass difficult to remove.

C-222. When boiler and setting are thoroughly cooled the blow-off valve shall be opened and the water removed. Then the manhole and handhole covers shall be removed to allow circulation of air.

C-223. The inside of shell, drums and tubes shall then be washed down thoroughly to remove mud, loose scale, etc. The washing operation shall be conducted from above as far as possible to carry the material downward to blow-off or lower handholes.

C-224. Before the washing operation is commenced a wire-gauze screen of cylindrical form shall be inserted in each blow-off opening, projecting up into the boiler several inches, whose function

is to prevent loose pieces of scale from entering and clogging the blow-off pipe.

C-225. The plant inspector shall have available the data on the boiler, dimensions, age, particulars as to previous defects noted, if any, and shall proceed to check up the pressure carrying capacity of boiler subject to conditions found during complete inspection.

External Inspection

C-226. The plant inspector shall examine the boiler for level, noting whether or not there has been any tendency to settlement, especially the level of the top tubes in horizontal-return-tubular boilers. He shall see that proper provision is made for expansion toward the back of boiler.

C-227. Examination shall then be made of the feed connection to see that it is clear and in good working condition.

C-228. Examination shall be made for evidences of corrosion on exterior of shell from rain coming down stack and leaking roofs, valves and pipes.

C-229. Inspection shall be made to see if there is any leakage of flame on dry sheets, particularly at the back arch of return-tubular boilers, which should be entirely clear of rear tube sheet with sheet metal or asbestos rope covering gap. Tie rods and buck stays shall be examined for condition and possible shifting from place.

C-230. Where the boiler top is covered with brick or other material, it should be removed sufficiently to allow proper inspection of riveted joints.

C-231. The plant inspector should note proximity of overhead shafts or any machinery which might drop down on or strike boiler in case of accident.

C-232. The plant inspector should note the presence of lumber, or other material piled on boiler or setting for purposes of drying or storage and which may endanger the setting or the safety and accessibility of the apparatus.

C-233. A careful examination shall be made of the safety valve, its connection to the boiler, escape pipe, its drip, supports, etc. He shall also test the safety valve by hand.

C-234. The water glass, gage cocks, water column connections and blow-offs shall be tested to see if the connections are free. Boiler pressure gages and master gages shall be tested.

Furnace and Parts Exposed to Fire

C-235. The plant inspector shall go into the furnace for the examination of the exterior of the tubes, shell, brickwork, etc.

C-236. He shall examine carefully for bulges over the fire, leaky rivets, loose rivets, rivets out of alignment, corrosion, wasting away of plates, cracks, etc.

C-237. The plant inspector shall scrape the shell and tap it thoroughly with hammer to detect thin places. He shall check thickness of plates with steel-scale measurement. He shall examine joints and sheets over the fire particularly for possible fire cracks.

C-238. The plant inspector shall examine the setting for cracks, settlement and loose brick which may lean against the boiler. Where brickwork is used as insulation of steel supporting numbers it shall be examined to see that it is in good condition and that the air space, if any, is maintained. The furnace lining shall be examined for spalling, cracking and settlement. In vertical boilers, bridge walls shall be inspected to see that the mud drum is properly protected. The plant inspector shall examine baffle and check walls particularly for holes which may permit flaming through.

C-239. The blow-off connection should be examined carefully for corrosion and weakness where it screws into the boiler. The protecting cover of brick or tile should be intact and not interfere in any way with the expansion of the boiler or pipe.

C-240. Particular attention shall be given the tube ends and tube sheets in the case of horizontal-return-tubular boilers, the plant inspector noting any corrosion of the sheets, signs of leaking tubes, excessive thinning of the tubes from repeated rollings, and any cracks in the tube ends.

C-241. The plant inspector shall note any tendency to corrosion from leakage of manhole and handholes under tubes in tube sheets of return-tubular boilers.

Internal Inspection

C-242. The plant inspector shall enter the drums of the boiler to make personal examination of conditions, first making sure that they have been properly ventilated and that there is no inflammable gas present from oil used to coat the boiler as the water level is lowered.

C-243. Before entering the shell or drum the plant inspector shall see that the blow-off valve, the main steam valve and other valves are locked and the keys in his possession.

C-244. Careful examination of the interior of the boiler shall be made for pitting, corrosion, scale and thin places in shell. The upper half of drums in the steam space shall be examined particularly for signs of grease and oil.

C-245. The interior of the tubes should be examined for scale and deposits and the space between the tubes in case of return-tubular boiler made visible by lowering candle or small light between them for the purpose of making sure that there is no restriction of the circulation.

C-246. The location of the feed discharge and condition of the trough under it shall be noted. Dry pipes shall be examined to see that their openings and perforations are free from deposits. All interior fittings shall be examined for loose connections.

C-247. The interior face of the riveted joints shall be examined for condition of riveting, thinness of metal, corrosion, cracks, etc. The plant inspector shall note any wasting away and cracking of stays and braces. Particular note shall be made of any welded stays or braces.

C-248. The fusible plug, if used, shall be examined, the top scraped to expose the condition of the metal and the plug renewed in case it has seen a year of service. The surface of the boiler about the plug shall also be scraped.

Inspection of Appurtenances and Supports

C-249. An examination of the condition of the main header and its connections to boiler shall be made to ascertain that it is properly supported, that due allowance is made for expansion without throwing strains on the boiler, that the non-return stop-valves are in good working condition and so placed that there is no pocket in the connection to hold water.

C-250. The plant inspector shall note the position of the steam gage, gage cocks, ascertain that the pipes leading to the water column and water glass are level, and by leveling across the top row of tubes or from the position of the fusible plug check the position of the water glass.

C-251. Check pipe line and all exterior supports to see that the proper tension and alignment is maintained. Where boiler foundations are independent of building foundations, joints on the steam and feed connections shall be disconnected once a year to check possible settlements.

C-252. In addition to the above inspections, the plant inspector shall observe the condition of the interior of boiler at least once in every three months or at more frequent intervals if the boiler is opened for cleaning or repairs. Each time the boiler is removed from service, the plant inspector shall look for signs of defects where observations cannot be taken while the boiler is in operation.

C-253. A record of each inspection shall be kept in a uniform manner so that any change of condition can be definitely compared especially with reference to thickness of scale, corrosion, cracks, etc.

Care and Management

C-254. The plant inspector shall note particularly any evidences of carelessness in the care and management of the boiler and its appurtenances.

C-255. The plant inspector shall demand immediate remedy of any unsafe conditions or undesirable practices he may uncover and shall report fully on the results of his inspection to the owners of the boiler plant, promptly.

C-256. The plant inspector shall be furnished a copy of all reports of inspections made by authorized inspectors and shall see that all recommendations in such reports are promptly and carefully carried to completion.

RULES FOR ROUTINE OPERATION

Putting Boilers in Service

C-257. Getting up Steam. In starting a new boiler or one that has been out of service for an extended period, see that the combustion chamber and gas passages are clean and in good repair. See that all clean-out doors are closed tight.

C-258. Operate and see that both inlet and outlet dampers are free and in good condition. Leave the back dampers open. Operate the stoker and draft fan to see that they are ready for service. Make sure that the grates are satisfactory and in place.

C-259. Examine the inside of the boiler and make sure that it is free from tools and foreign matter and that there is no one in the boiler; then close manhole openings.

C-260. See that blow-off valves, water column and water-glass drains, try cocks and feed valves are in good working condition and closed. Open vent valves.

C-261. By means of auxiliary feedwater connections, fill the the boiler with water to a level a little above the surface blow-off and then close the auxiliary feed connections. Open and close try cocks and blow-down valves on water column and water glass in order to make sure that these connections are not stopped up.

C-262. Draw off water through surface and bottom blow-off valves until the level of the water in the boiler is at the bottom of the water glass and then raise the level of the water to a point about 1/2 in. below the normal water line by opening the stop valve in the main feed line.

C-263. Ease up on the stem of the main stop valve without lifting the valve off the seat in order to make sure that the valve is not stuck.

C-264. Open valves to steam pressure gage.

C-265. If coal is used as a fuel, cover the grate with a thin layer of coal and start a light fire. Where pulverized coal, gas or oil is used as a fuel, make sure that the back damper is wide open, create light draft, with fan if necessary, place torch or fire near burner to insure quick ignition and start light fire by admitting fuel slowly.

C-266. If the boilers use oil as a fuel and the system is new or has been out of service for a considerable period, first clean and examine the strainers and remove, clean and examine tips and burners. If compressed air is available, blow out the oil supply lines with air. Place and adjust burners and tips and work the air registers to see that they are in good working condition. Close individual burner throttle valves.

C-267. Remove any spilled oil about burners, fronts and floor and see that there is no oil on the floor of the combustion chamber. Ventilate the boiler by opening draft gates and dampers.

C-268. If no steam is available for oil pump and burners, raise steam in boiler by wood fire. Remove any excess accumulation of water in oil tank. Have oil pumps warmed up ready for use. Open suction-line valves and pump oil to burners. If oil lines are equipped with air chambers, charge them with compressed air. Examine oil lines and equipment for leaks.

C-269. Light the center burner by holding hand torch near and just under tip or burner standing well clear to avoid possible flare back. If torch is snuffed out before oil is lighted shut off the oil and relight the torch. Always use the torch for lighting burners until the brickwork is intensely hot and even then if all burners are out. Next light the adjacent burners but be sure that there is an excess of draft before lighting additional burners. Do not permit the oil to impinge on the brickwork or parts of the boiler.

C-270. Test the steam coils in the heater for oil.

C-271. After starting a light fire and if the entire setting is new, the fire should continue until the brickwork is dried out thoroughly which in the average case takes several days; if the combustion chamber only has been renewed keep the fire going about 48 hours. After the usual week-end shut down, a light fire should be carried for about one hour. Only in extreme emergency should steam be raised in less than a half hour. Do not permit the fire to generate a steam pressure until about thirty minutes before cutting the boiler into the line.

C-272. In case of a new setting, ease up on buck stays and tie rods to allow for possible expansion of the brickwork. After water becomes heated, check the level of the water in the glass with try cocks and examine blow-offs for leaks. After steam has escaped through the vent valves for a few minutes, close the valves.

C-273. After brickwork is dried out and the boiler heated, begin raising the steam pressure slowly, especially in internally fired boilers where the circulation is sluggish. Keep the water level constant. When the steam pressure approaches the working pressure, examine the boiler for leaks, blow out the pressure gage connections and test the safety valve by hand. Blow down boiler to remove sediment.

C-274. If the boiler is equipped with a superheater of the indirectly fired type not constructed to withstand the intense heat during the firing up period, see that it is protected before lighting the fire by flooding or by closing dampers installed for the purpose.

C-275. Cutting In. Drain very thoroughly the steam connections between the boiler and the header or steam main. Where a non-return check valve or stop and check valve is not installed, the stop valve shall be opened very slowly and only when the pressure in the boiler is exactly the same as the pressure in the header. If the main stop valve has a by-pass, the by-pass should be used until the pressures are equalized. In any case the stop valve shall be opened very slowly and the operator should stand by for a few minutes after the stop valve has been opened wide; if any disturbance or hammer occurs in the boiler or in the pipe line, close the stop valve at once. If a non-return check valve or stop and check valve, as the case may be, is installed, open the stop valve when the pressure in the boiler is 10 or 15 lb. less than the pressure in the header, and let the non-return check operate automatically.

Firing Boilers

C-276. Uniform Firing. Aside from the standpoint of economy, the fire should be maintained as uniformly as possible in order to avoid excess combustion, undesirable variations in temperature and possible gas explosions.

C-277. Cleaning Fire. Fires should be cleaned at stated periods, if possible, and when boilers are operating at low rating as at noontime and just before peak loads. Avoid holes in fire and excessive draft while burning out the fire. Clean fires as rapidly as possible to minimize cold air in the boiler. Do not fire too heavily immediately after cleaning. Do not pile hot ashes and clinkers against boiler front, use care in quenching and remove ashes as soon as possible.

C-278. Banking Fire. Do not bank fires any more than necessary. When fires are banked, make sure that a continuous light current of air is passed through the boiler. This is usually accomplished by having the ashpit doors closed, the firing doors slightly opened and the back damper perforated or nearly closed.

Handling Boilers in Service

C-279. Water Level. The most important rule in the safe operation of boilers is to keep water in the boiler and as constantly at the proper level as conditions will permit. Never depend upon automatic alarms or feedwater regulators. Any inattention, other duties or reliance upon automatic devices cannot be accepted as an excuse for a boiler damaged by low water level.

C-280. The first duty on entering the boiler room is to ascertain whether the valves and connections between the boiler and water column are free and open especially when starting up in the morning after the fires have been banked over night. Then blow down the water column, noting the return of the water in the glass, and try the gage cocks until sure of the water level. This should be done at the beginning and end of each shift and also several times during the shift. Have the water column well lighted and keep the water glass clean. Do not allow steam to leak from the water column or its connections, as this will cause the water glass to show a false level.

C-281. If the level of the water is not visible in the water glass, try the gage cocks to determine whether the level of the water is above or below the water glass. If the level is below the water glass, stop the supply of fuel immediately and then the supply of air; close the dampers and ashpit doors. Close the feedwater valve and under no circumstances feedwater into the boiler. Haul the fire and, in the case of stokers or chain grates, keep them in motion with the fire doors open. Do not throw water on th

fire with fire or other hose. Do not open the safety valve or change the steam outlet valves or make any changes that will cause a sudden change in the stresses acting upon the boiler. Examine the bottom blow-off valves and repair them if they are found defective. Find the cause of the failure of the supply of water.

C-282. *Foaming and Priming.* If foaming occurs check the fuel supply and close the steam outlet valve long enough to determine the true level of the water in the glass. If the level of the water in the water glass is sufficiently high, blow down some of the water in the boiler and feed in fresh water. Use surface blow-off if any are installed. Repeat the alternate blowing-off and feeding several times, and if the foaming does not stop, draw the fire and continue the alternate blowing-off and feeding. When the boiler is sufficiently cooled off, empty the boiler and look for the cause of the foaming which may be caused by oil or other foreign matter in the feedwater or by scale solvent. Test safety valve and connections of water column and water glass for any choking or sticking. Determine positively the cause of foaming and adopt measures to prevent its recurrence.

C-283. *Oil in Boiler.* Watch carefully for any signs of oil in the feedwater heaters, water glasses and blowdowns. If a boiler becomes coated with oil or grease, shut down the boiler and clean it thoroughly. If the amount of oil is considerable, boil out in accordance with Par. C-311.

C-284. *Feedwater Treatment.* Execute carefully all instructions given for the treatment of feed water in your particular boiler room. Do not experiment with "home made" treatments or boiler compounds, unless advised to do so by a chemist experienced in feedwater treatment.

C-285. *Blowing Off.* Except where the amount and frequency of blowing down is determined by chemical analysis, blow down at least one gage every twenty-four hours. The amount of blowdown depends upon the number of hours per day the boiler is in service, the rate at which it operates and the kind of feedwater used. Blow down the boilers at a period in the day when the circulation of water in the boiler is slowest. Always open the cock first and the valve second; in closing, close the valve first and the cock second. Always open and close the blow-off valves carefully and slowly; if unusual effort is necessary to close the valve or cock, do not try to force them shut but empty the boiler and find the cause. In blowing down, open the cock or valve until it is half open and leave in that position until the water is blown down about $^1/_2$ in. in the water glass; then open the cock or valve wide open until the blowing off is completed. See that the valve shuts tight and remains tight. Repair all leaky blow-offs as soon as discovered. Use the surface blow-off frequently for a short period of time.

C-286. Where the water glass is not in view of operator blowing down a boiler, another operator shall be stationed where he can see the water glass and signal to the operator who is blowing down the boiler.

C-287. *Leaks.* When small leaks occur, locate their source and repair them as soon as boiler can be removed from service. If a serious leak occurs such as a leak along the longitudinal seams, shut down the boiler immediately by gradually reducing the steam pressure and have the boiler examined by an authorized inspector.

C-288. *Repairs.* Do not make any repairs upon a boiler, piping or auxiliaries while they are under steam pressure. Calking of pipes and joints and setting up of nuts and bolts under pressure to stop leakage must be prohibited.

C-289. *Removal of Soot and Ashes.* Soot should be dusted from the tubes once a day; whether a lance or soot blower is used, drain the steam or air-supply connections so that the steam or air is practically dry. Never use steam for dusting off tubes when the boiler is not under pressure. When a boiler is to be shut down, dust the tubes before the fire has died out and with the draft on after the boiler has been cooled, brush or scrape any hardened soot or deposit from the tubes.

C-290. Remove ashes frequently and do not permit the accumulation of any large amount of ashes in the ash pit, boilers, flues or base of stacks. Do not pile ashes against the furnace front and, when wetting down ashes, make sure that no water is thrown upon hot castings. Do not leave ashes banked about blow-off pipes as a protection.

C-291. When ashes are removed by a suction system, an explosion door shall be provided on the storage hopper. Where steam-jet ash conveyors are used, see that all operatives are warned against the water which may collect upon the top of the ashes in the hopper and may flow suddenly from the gate when the ashes are being removed. When necessary to bar through the gate to release clogged ashes, the operator shall be warned to stand sufficiently aside to avoid being burned by the hot ashes or water.

Care of Appliances

C-292. *Safety Valves.* Test the safety valves at least once a day by gently raising the valve off the seat by hand or, when practicable, test the valves daily by raising the steam pressure to the blowing pressure of the safety valve. If the valve sticks do not try to release it by hammering; drop the pressure in the boiler and clean the valve seat or correct any other defect that may be found. Repair or replace leaking safety valves as soon as discovered.

C-293. When a safety valve blows, note the pressure on the boiler steam gage and, if the stipulated blowing pressure varies more than 5 lb. from the pressure noted on the gage, test the gage. If the gage is found correct, adjust the safety valve.

C-294. Do not permit setting or adjustment of safety valves by any one but a competent person. Do not have the water in boiler above the highest gage cock when setting or adjusting the valve. When the spring becomes weak and must be screwed down to secure the stipulated blowing pressure, make sure that the spring is not screwed down so far that there is a restriction of the proper amount of opening of the valve as called for in Pars. 282 and 284 of the Rules for the Construction of Power Boilers.

C-295. Do not open the safety valve to reduce the pressure in the case of low water in the boiler.

C-296. Never set the blowing point of a safety valve above the authorized pressure of the boiler.

C-297. When making a hydrostatic test do not try to hold the safety valve closed by screwing down the spring; blank the valve, clamp the seat in place or use some other suitable method. Make sure that the safety valve is placed in good working condition after the hydrostatic test has been made.

C-298. Keep scale, dirt or other foreign matter from collecting between the coils of the spring. When running a wire in the drain hole in the escape pipe to ascertain if it is clear, be careful that the wire does not move scale that may fall over the drain opening when the wire is removed.

C-299. *Steam Pressure Gage.* Blow down the gage connections frequently and especially when checking the safety valve, raising steam in a boiler and when foaming occurs.

C-300. *Water Glass.* When a water glass has broken, remove the broken pieces and, with head turned away from the water column, slowly open the bottom valve to blow out any remaining pieces. Before inserting the new glass, see that the glass is of the exact length required and that the connections are in line. Insert the glass and set up the stuffing-box nuts taking care not to set them up too tight. Then warm the glass by opening the drain cock of the glass and with head turned aside, open the top valve slightly and let a small current of steam flow through the glass. Close the drain cock after the glass is sufficiently warmed, open the bottom valve slightly and when the level of the water in the glass has become stable, open the bottom valve wide and then open the top valve wide, all the while keeping the face turned to one side.

C-301. Water glasses must be kept clean. Do not clean a glass with waste or linty cloth; use cloth, free from lint and dirt, wound about a wooden stick. Do not use a metal rod that would scratch the glass and start a crack.

Handling Boilers out of Service

C-302. *Cutting Out.* To cut out a boiler, first cut off the supply of fuel. In a coal-fired boiler close ashpit and fire doors and close dampers. In an oil-fired boiler, continue the air supply until any oil on the floor of the combustion chamber is consumed and the gas passages are well ventilated; then close dampers. After the boiler ceases to require feed water and the non-return check valve, if any, on the steam line has closed, close the main steam stop valve. When possible blow off the tubes before the fire has died out. Fill the boiler to three-fourths of a glass.

C-303. Cooling Off. After the fires have died out, close all doors and open dampers. When the pressure has dropped to blowing down pressure (see Par. C-304), clean the furnace of all coal and ashes and permit the brickwork to cool for not less than two hours. When there is much sediment in the boiler, longer time must be allowed.

C-304. Emptying. After cooling off the setting, open the blow-off valves when the pressure in the boiler has been reduced to about 10 lb. if it is not feasible to empty the boiler at atmospheric pressure. When the boiler to be emptied is set in a battery, make sure the blow-off valves that are opened are on the boiler which is to be emptied. As soon as the boiler is empty, remove the manhole plates and covers of other openings.

C-305. Cleaning. Examine boiler frequently to determine how often the boiler should be washed. Wash more frequently when the boiler runs longer hours per day or at higher ratings, when feed water becomes foul or when scale solvents throw down scale.

C-306. Remove manhole and handhole plates, close feed valves, steam outlet valves and blow-off valves and hang sign on boiler to indicate that a man is working inside.

C-307. Use hose with considerable force or hand tools, if necessary, to remove scale. Disconnect blow-off pipe close to the boiler and run the water to waste. Horizontal-tubular boilers should be washed from below as well as from above. See that the water does not get on the brickwork of the combustion chamber.

C-308. After washing the boiler pass a light inside and see that the cleaning has been thorough and that no tools are left inside. If the boiler has been treated with kerosene in the feed water, ventilate the boiler; do not use a naked flame to examine the boiler.

C-309. Do not remove scale with kerosene if it can be done by any other means. If it is used, see that the boiler is dry and cool. Do not use kerosene in large quantities in a room where other boilers are in service unless special precautions are taken to keep the vapors from escaping into the boiler-room. Keep all lights away from the boiler except incandescent lamps enclosed in moisture-proof globes and guards.

C-310. Spray the inside of the boiler and, after allowing it to stand a sufficient length of time, wash thoroughly with hose and copious amount of water. Do not enter the boiler until it has been thoroughly ventilated. Also ventilate the boiler before entering it the next time that it is opened.

C-311. When boiler has been allowed to become heavily scaled or coated with oil it may be cleaned by boiling out with soda ash and kerosene. Fill boiler well above water line with water containing 50 lb. of soda ash and 5 gallons of kerosene to 1000 gallons of water. Close the boiler and start light fire sufficient to carry about 5 lb. pressure in the boiler. Continue boiling for two or three days, empty the boiler, then wash thoroughly and ventilate the boiler. Use the usual precaution against oil vapors.

C-312. When cleaning scale from tubes with mechanical hammer or cleaner follow the instructions given in Par. C-185.

C-313. Laying-Up. When laying-up a boiler for an extended period of time, follow the instructions given in Pars. C-152 to C-155, inclusive.

Second Revision of A.S.M.E. Boiler Code, 1923

A HEARING is held by the Boiler Code Committee at least once in four years, at which all interested parties may be heard, in order that such revisions may be made as are found to be desirable, as the state of the art advances. The year 1922 became the period of the second revision and the Boiler Code Committee held a Public Hearing in connection with the recent Annual Meeting of the Society in December, 1922, to which the membership of the Society and every one interested in the steam-boiler industry was invited to come and present their views.

For the convenience of every one interested, a printed schedule of the various proposed revisions had been published and distributed to all those who were invited to attend the Public Hearing and the opportunity was given thereat for the most careful consideration of all of the proposed revisions. As a result of the suggestions received at the Public Hearing, a number of modifications of the previously announced revisions were offered and in addition suggestions were received for still further revisions of the Code. All of these suggestions for modifications and new revisions have been carefully considered by the Boiler Code Committee and the result in modifications of revisions and additional revisions are here published.

It is the request of the Committee that these revisions be fully and freely discussed so that it may be possible for any one to suggest changes before the rules are brought to final form and presented to the Council for approval. Discussions should be mailed to C. W. Obert, Secretary of the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be considered by the Boiler Code Committee.

The revisions here published are limited to the paragraphs appearing in the 1918 Edition of the A.S.M.E. Boiler Code, and the paragraph numbers refer to the paragraphs of similar number in that edition. For the convenience of the reader in studying the revisions, all added matter appears in small capitals and all deleted matter in smaller type in brackets.

In addition, there are here presented the revisions of the material specifications that have been approved by the Boiler Code Committee, to replace the specifications in the present edition of the Code, Pars. 23–178.

Modifications of Revisions

PAR. 250. REVISE FIRST TWO SENTENCES OF FORM GIVEN IN DECEMBER, 1922, ISSUE OF MECHANICAL ENGINEERING AS FOLLOWS:

250. A fire-tube boiler with tubes under 5 in. diameter shall have the ends of the tubes firmly rolled and beaded, or rolled, BEADED and welded at the firebox or combustion-chamber end, and rolled and beaded at the other end. In the case of tubes under $1^1/_2$ [$1^1/_4$] in. diameter, THEY [tubes] may be expanded by the Prosser method in place of rolling.

PAR. 308. ADD THE FOLLOWING TO THE REVISED FORM GIVEN IN THE JULY, 1922, ISSUE OF MECHANICAL ENGINEERING:

FOR PRESSURES NOT IN EXCESS OF 100 LB., RETURN CONNECTIONS OF THE SAME SIZE OR LARGER THAN THE SIZE HEREIN SPECIFIED MAY BE USED, AND TO WHICH THE BLOW-OFF MAY BE CONNECTED. IN SUCH CASE THE BLOW-OFF MUST BE SO LOCATED THAT THE CONNECTION MAY BE COMPLETELY DRAINED.

PAR. 318. ADD THE FOLLOWING TO THE REVISED FORM GIVEN IN THE AUGUST, 1922, ISSUE OF MECHANICAL ENGINEERING:

ON BOILERS HAVING MORE THAN 100 SQ. FT. OF HEATING SURFACE, THE FEED PIPE SHALL BE NOT LESS THAN $^3/_4$ IN. IN DIAMETER.

New Revisions

PAR. 301. REVISED:

Each steam-discharge outlet [over 2 in. in diameter] except safety-valve and superheater connections, shall be fitted with a stop valve [or valves of the outside-screw and yoke type], located as near the boiler as practicable. WHEN SUCH OUTLETS ARE OVER 2 IN. PIPE SIZE, THE VALVE OR VALVES USED ON THE CONNECTION SHALL BE OF THE OUTSIDE-SCREW AND YOKE TYPE.

MATERIAL SPECIFICATIONS

GENERAL RULES FOR INSPECTION AND TESTS

S-1. Inspection. At all times, while work on the contract of the purchaser is being performed, the inspector, representing the

purchaser, shall have free entry to all parts of the manufacturer's works which concern the manufacture of the material ordered. The manufacturer shall afford the inspector, without charge, all reasonable facilities to satisfy him that the material is being furnished in accordance with the specifications. Unless otherwise specified, all tests (except check analyses) and inspection shall be made at the place of manufacture, prior to shipment, and shall be so conducted as not to interfere unnecessarily with the operation of the works.

S-2. Rejections. *a* Rejections based on tests made by the purchaser under the provisions of the specifications shall be reported to the manufacturer within five working days from the receipt of samples.

b Material which shows injurious defects subsequent to its acceptance at the manufacturer's works will be rejected, and the manufacturer shall be notified.

S-3. Rehearing. Samples which represent rejected material, tested by the purchaser under the provisions of these rules, shall be preserved for two weeks from the date of the test report. In case of dissatisfaction with the results of the tests, the manufacturer may make claim for a rehearing within that time.

S-4. Ladle Analyses. *a* The manufacturer shall make an analysis of each melt of steel, from a test ingot taken during the pouring of the melts, to determine the percentage of carbon, manganese, phosphorus, and sulphur. The results of analysis shall conform to requirements, and shall be reported to the purchaser, or his representative.

Check Analyses. *b* The purchaser may make an analysis from finished material representing each melt. The chemical composition thus determined shall conform to the requirements.

Physical Tests. *c* The yield point shall be determined by the drop of the beam of the testing machine. For determination of the yield point the speed of the crosshead of the machine shall not exceed $^1/_2$ in. per minute when the elongation is taken in 2 in., nor exceed 2 in. per minute when the elongation is taken in 8 in. After the yield point has been passed the speed of the machine may be increased to not more than 2 in. per minute when the elongation is taken in 2 in., nor more than 6 in. per minute when the elongation is taken in 8 in.

SPECIFICATIONS FOR STEEL BOILER PLATE

Note: This specification is printed merely for information and is not in its final approved form. The Boiler Code Committee feels that additional protection should be secured in the case of firebox steel and has suggested to the American Society for Testing Materials and the Association of American Steel Manufacturers that an additional chemical check analysis from the top of the plate and possibly an additional tensile test also from the top of the plate should be provided for this class of steel. The replies of these organizations have not been received and the final form that this specification will take will depend upon the actions of these associations.

S-5. Classes. These specifications cover two classes of steel for boilers, namely: flange and firebox.

S-6. Process. The steel shall be made by the open-hearth process.

S-7. Chemical Composition. The steel shall conform to the following requirements as to chemical composition.

		Flange	Firebox
Carbon		Plates $^3/_4$ in. thick or under: not over 0.25 per cent	
		Plates over $^3/_4$ in. thick: not over 0.30 per cent	
Manganese	Plates $^3/_4$ in. thick or under	0.30–0.60	0.30–0.50
	Plates over $^3/_4$ in. thick	0.30–0.60	0 30–0.60
Phosphorus	Acid	Not over 0.05 per cent	Not over 0.04 per cent
	Basic	Not over 0.04 per cent	Not over 0.035 per cent
Sulphur		Not over 0.05 per cent	Not over 0.04 per cent

S-8. Check Analyses. As a substitute for check analyses in the general rules, the purchaser may make an analysis from a broken tension-test specimen representing each plate as rolled. The chemical composition thus determined shall conform to the requirements. For firebox steel, the purchaser may also make an analysis from a bend-test specimen representing each plate as rolled. The chemical composition thus determined shall not exceed the requirements by more than 10 per cent.

S-9. Tension Tests. *a* The material shall conform to the following requirements as to tensile properties:

	Flange	Firebox
Tensile strength, lb. per sq. in	55,000–65,000	55,000–65,000
Yield point, min., lb. per sq. in	0.5 tens. str.	0 5 tens str.
Elongation in 8-in., min. per cent (See Par. S-10*a*)	$\frac{1,500,000}{\text{Tens. str.}}$	$\frac{1,550,000}{\text{Tens. str.}}$

b Should the above rule for minimum allowable elongation give a value less than 25 per cent for firebox steel, the minimum allowable elongation shall be taken as 25 per cent, subject to the modification given.

c The tensile strength of the test specimen taken longitudinally from the top of the plate for firebox steel shall not exceed 70,000 lb. per sq. in.

S-10. Modifications in Elongation. *a* For material over $^3/_4$ in. in thickness, a deduction from the percentages of elongation specified of 0.125 per cent shall be made for each increase of $^1/_{32}$ in. of the specified thickness above $^3/_4$ in. to a minimum of 20 per cent.

b For material $^1/_4$ in. in thickness, the elongation shall be measured on a gage length of 6 in.

S-11. Bend Test. The bend-test specimen shall bend cold through 180 deg. without cracking on the outside of the bent portion, as follows: For material 1 in. or under in thickness, around a pin the diameter of which is equal to the thickness of the specimen; and for material over 1 in. in thickness, around a pin the diameter of which is equal to twice the thickness of the specimen.

S-12. Homogeneity Tests. For firebox steel, a sample taken from a broken tension-test specimen shall not show any single seam or cavity more than $^1/_4$ in. long in either of the three fractures obtained in the test for homogeneity, which shall be made as follows:

The specimen shall be either nicked with a chisel or grooved on a machine, transversely, about $^1/_{16}$ in. deep, in three places about 2 in. apart. The first groove shall be made 2 in. from the square end; each succeeding groove shall be made on the opposite side from the preceding one. The specimen shall then be firmly held in a vise, with the first groove about $^1/_4$ in. above the jaws, and the projecting end broken off by light blows of a hammer, the bending being away from the groove. The specimen shall be broken at the other two grooves in the same manner. The object of this test is to open and render visible to the eye any seams due to failure to weld or to interposed foreign matter, or any cavities due to gas bubbles in the ingot. One side of each fracture shall be examined and the length of the seams and cavities determined, a pocket lens being used if necessary.

S-13. Test Specimens. *a* Tension-test specimens shall be taken longitudinally from the bottom of the finished rolled material, and bend-test specimens shall be taken transversely from the middle of the top of the finished rolled material. The longitudinal test specimen shall be taken in the direction of the longitudinal axis of the ingot, and the transverse-test specimen at right angles to that axis. For firebox steel, an additional tension-test specimen shall be taken longitudinally from a top corner of the finished rolled material.

b Tension- and bend-test specimens shall be of the full thickness of material as rolled, and shall be machined to the form and dimensions shown in Fig. 1; except that bend-test specimens may be machined with both edges parallel.

(Fig. 1, A.S.M.E. Code [1918], page 13, to be inserted.)

S-14. Number of Tests. *a* One tension- and one bend-test shall be made from each plate as rolled. For firebox steel an additional tension test will be made from the top of the plate. Tensile strength only will be determined from this specimen.

b If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

c If the percentage of elongation of any tension-test specimen is less than that specified and any part of the fracture is outside the middle third of the gaged length, as indicated by the scribe scratches marked on the specimen before testing, a retest shall be allowed.

S-15. Permissible Variation. The thickness of each plate shall not vary under the gage specified more than 0.01 in. (The overweight limits are considered a matter of contract between the steel manufacturer and the boiler builder.)

S-16. Finish. The finished material shall be free from injurious defects and shall have a workmanlike finish.

S-17. Marking. *a* The name or brand of the manufacturer, the manufacturer's test identification number, class and lowest

tensile strength specified shall be legibly stamped on each finished plate in two places not less than 12 in. from the edges and on each butt strap near the center line not less than 12 in. from each end. Manufacturer's test identification number shall be legibly stamped on each test specimen.

SPECIFICATIONS FOR STEEL BOILER RIVETS

Note: This specification has not been approved by the Boiler Code Committee and is not in its final form, being printed for information only. An agreement has not been reached with the manufacturers of boiler rivets in regard to the tolerances for finished rivets. The tolerances as given in the specifications printed herewith are those which the Boiler Code Committee believe are reasonable. Some objections have, however, been raised to these tolerances by rivet manufacturers, and the Boiler Code Committee will take no final action on this specification until an agreement is reached as to what reasonable tolerances for the finished rivets should be.

A—Requirements for Rolled Bars

S-18. Process. The steel shall be made by the open-hearth process.

S-19. Chemical Composition. The steel shall conform to the following requirements as to chemical composition:

Manganese	0.30–0.50 per cent
Phosphorus	not over 0.04 per cent
Sulphur	not over 0.045 per cent

S-20. Tension Tests. The bars shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in.	45,000–55,000
Yield point, min., lb. per sq. in.	0.5 Tens. Str.
Elongation in 8 in., min., per cent but need not exceed 30 per cent	$\frac{1,500,000}{\text{Tens. Str.}}$

S-21. Bend Tests. a Cold-Bend Tests. The test specimen shall bend cold through 180 deg. flat on itself without cracking on the outside of the bent portion.

b Quench-Bend Tests. The test specimen, when heated to a light cherry red as seen in the dark (not less than 1200 deg. fahr.), and quenched at once in water the temperature of which is between 80 deg. and 90 deg. fahr., shall bend through 180 deg. flat on itself without cracking on the outside of the bent portion.

S-22. Test Specimens. Test specimens shall be of the section of the bars as rolled. Tension- and bend-test specimens for rivet bars which have been cold-drawn shall be normalized before testing.

S-23. Number of Tests. *a* Two tension, two cold-bend, and two quench-bend tests shall be made from each melt, each of which shall conform to the requirements specified.

b If any test specimen develops flaws, it may be discarded and another specimen substituted.

c If the percentage of elongation of any tension-test specimen is less than that specified and any part of the fracture is outside the middle third of the gaged length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

S-24. Permissible Variation in Gage. The diameter of each bar shall not vary from that specified more than the amount given in the following table:

Diameters, In.	Variation in Diameter: Under, In.	Variation in Diameter: Over, In.	Out of Round, In.
Up to 1/2, inclusive	0.007	0.007	0.010
Over 1/2 to 1, inclusive	0.010	0.010	0.013
Over 1 to 1 1/4, inclusive	0.012	0.012	0.016
Over 1 1/4 to 1 1/2, inclusive	0.015	0.015	0.021
Over 1 1/2 to 2, inclusive	0.022	0.022	0.023

S-25. Finish. The finished bars shall be free from injurious defects and shall have a workmanlike finish.

S-26. Marking. Rivet bars shall, when loaded for shipment, be properly separated and marked with the name or brand of the manufacturer and the melt number for identification. The melt number shall be legibly marked on each test specimen.

B—Requirements For Rivets

S-27. Bend Tests. The rivet shank shall bend cold through 180 deg. flat on itself, as shown in Fig. 2, without cracking on the outside of the bent portion.

S-28. Flattening Tests. *a* The rivet head shall flatten, while hot, to a diameter 2 1/2 times the diameter of the shank, as shown in Fig. 3, without cracking at the edges.

b Three bend and three flattening tests shall be made from each size in each lot of rivets offered for inspection, each of which shall conform to the requirements specified.

(Figs. 2 and 3, A.S.M.E. Code [1918], page 18, to be inserted here.)

S-29. Permissible Tolerances. The diameter of the shank of finished rivets measured at any point between the fillet under the head and a point two-thirds of the length from the head to the end of the shank, shall not vary from the nominal diameter more than the amount given in the following table:

Diameters, In.	Variation in Diameter: Under, In.	Variation in Diameter: Over, In.	Out of Round, In.
Up to 1/2, inclusive	0.022	0.007	0.010
Over 1/2 to 1, inclusive	0.025	0.010	0.013
Over 1 to 1 1/4, inclusive	0.027	0.012	0.016
Over 1 1/4 to 1 1/2, inclusive	0.030	0.015	0.021
Over 1 1/2 to 2, inclusive	0.037	0.022	0.023

The dimensions of the rivet head shall not vary more than two per cent over or under, from those specified.

SPECIFICATIONS FOR STEEL STAYBOLTS

S-30. Solid or Hollow Staybolts. Steel for solid or hollow staybolts shall conform to the requirements for Boiler Rivet Steel specified, except that the tensile properties shall be as follows:

Tensile strengh, lb. per sq. in.	50,000–60,000
Yield point, min, lb. per sq. in.	0.5 Tens. Str.
Elongation in 8-in., min., per cent	$\frac{1,500,000}{\text{Tens. Str.}}$

The permissible variations in gage shall be as given in Par. S-32.

S-31. Seamless Tubing for Staybolts. *a* Seamless steel tubing for threaded steel staybolts shall conform to the requirements for Boiler Rivet Steel specified, with the exceptions as given herewith. This specification will not apply to stay tubes for locomotive boilers.

Chemical Composition. *b* The chemical composition shall conform to the requirements for Seamless Steel Tubes.

Physical Requirements. *c* The physical requirements shall be as follows:

Tensile strength, lb. per sq. in., minimum	48,000
Yield point, min., lb. per sq. in.	25,000
Elongation in 8-in., min., per cent	$\frac{1,500,000}{\text{Tens. Str.}}$

Tests. *d* Two tests from each 2500 feet of tubing may be made in absence of tests from each melt.

To insure sound and fine-grained structure, a special fracture test shall be made from at least each 2500 feet of tubing by cutting partly through the wall of the tube and breaking it off when removing the crop end. The fracture thus produced shall be fine-grained. This test will be used in place of the cold and hot quench bend tests specified.

e Ladle analysis will not be required.

f The marking requirement for rivet bars will not be required.

S-32. Permissible Variations in Gage. Solid or hollow bars for staybolts, not exceeding 1 1/4 in. diameter, which are to be threaded as rolled, shall be truly round within 0.01 in. and shall not vary more than 0.005 in. under or more than 0.01 in. over. All other bars for staybolts shall conform to the specified tolerances for Rivet Bars.

SPECIFICATIONS FOR STEEL BARS

S-33. Process. The steel shall be made by the open-hearth process.

S-34. Chemical Composition. The steel shall conform to the following requirements as to chemical composition:

Phosphorus	Acid	Not over 0.05 per cent
	Basic	Not over 0.04 per cent
Sulphur		Not over 0.05 per cent

S-35. Tension Tests. *a* The material shall conform to the following requirements as to tensile properties:

Tensile strength, lb. per sq. in.	55,000–65,000
Yield point, min. per sq. in.	0.5 Tens. Str.
Elongation in 8-in., min. per cent	$\frac{1,500,000}{\text{Tens. Str.}}$
Elongation in 2-in., min., per cent	26

S-36. Modifications in Elongation. For material over $^3/_4$ in. in thickness, a deduction from the percentages of elongation specified of 0.125 per cent shall be made for each increase of $^1/_{32}$ in. of the specified thickness above $^3/_4$ in.

S-37. Bend Tests. a Test specimen shall bend cold through 180 deg. without cracking on the outside of the bent portion, except as specified in section *b*, as follows: For material 1 in. or under in thickness or diameter flat on itself; for material over 1 in. to and including $1^1/_2$ in. in thickness or diameter around a pin the diameter of which is equal to the thickness or the diameter of the specimen; and for material over $1^1/_2$ in. in thickness or diameter around a pin the diameter of which is equal to twice the thickness or diameter of the specimen.

b The 1-in. by $^1/_2$-in. test specimen for bars over $1^1/_2$ in. in thickness or diameter shall bend cold through 180 deg. around a $^1/_2$-in. pin without cracking on the outside of the bent portion.

S-38. Test Specimens. a Test specimens shall be of the full thickness or diameter of material as rolled, except as specified in sections *b* and *c*.

b Test specimens for shapes and flats may be machined to the form and dimensions shown in Fig. 1, or with both edges parallel.

c Test specimens for bars over $1^1/_2$ in. in thickness or diameter may be machined to a thickness or diameter of at least $^3/_4$ in. for a length of at least 9 in.; or tension-test specimens may conform to the dimensions shown in Fig. 4. Bend-test specimens may be 1 in. by $^1/_2$ in. in section.

S-39. Number of Tests. a One tension and one bend test shall be made from each melt; except that if material from one melt differs $^3/_8$ in. or more in thickness, one tension and one bend test shall be made from both the thickest and the thinnest material rolled.

b If any test specimen shows defective machining or develops flaws, it may be discarded and another specimen substituted.

c If the percentage of elongation of any tension-test specimen is less than that specified and any part of the fracture is more than $^3/_4$ in. from the center of the gage length of a 2-in. specimen or is outside the middle third of the gage length of an 8-in. specimen, as indicated by scribe scratches marked on the specimen before testing a retest shall be allowed.

S-40. Permissible Variation in Gage. The diameter of each bar shall not vary from that specified more than the amount given in the following table:

Diameters, In.	Variation in Diameter Under, In.	Variation in Diameter Over, In.	Out of Round In.
Up to $^1/_2$, inclusive	0 007	0 007	0 010
Over $^1/_2$ to 1, inclusive	0 010	0.010	0 013
Over 1 to $1^1/_4$, inclusive	0 012	0.012	0 016
Over $1^1/_4$ to $1^1/_2$, inclusive	0 015	0 015	0 021
Over $1^1/_2$ to 2, inclusive	0 022	0.022	0 023
Over 2 to $2^1/_2$, inclusive	$^1/_{64}$	$^3/_{64}$	0 023
Over $2^1/_2$ to 3, inclusive	$^1/_{32}$	$^3/_{64}$	0 035

S-41. Finish. The finished material shall be free from injurious defects and shall have a workmanlike finish.

S-42. Marking. Bars shall, when loaded for shipment, be properly separated, and marked with the name or brand of the manufacturer and melt number for identification. The melt number shall be legibly marked on each test specimen.

SPECIFICATIONS FOR STEEL CASTINGS

S-43. Material Covered. These specifications cover two classes of castings, namely:

Class A, ordinary castings for which no physical requirements are specified;

Class B, castings for which physical requirements are specified.

S-44. Process. The steel shall be made by one or more of the following processes: open-hearth, electric-furnace, side-blow converter or crucible.

S-45. Heat Treatment. a Class A castings need not be annealed unless so specified, or unless the carbon content exceeds 0.30 per cent.

b Class B, castings shall be properly annealed, the treatment depending upon the design and chemical composition of the castings.

S-46. Chemical Composition. The castings shall conform to the following requirements as to chemical composition:

		Class A	Class B
Carbon		Not over 0.45 per cent	
Phosphorus	Acid	Not over 0 07 per cent	......
	Basic	Not over 0.06 per cent	Not over 0.05 per cent
Sulphur			Not over 0.05 per cent

(For Class B Castings Only.)

S-47. Tension Tests. a The castings shall conform to the following minimum requirements as to tensile properties:

Yield point, lb. per sq. in	29,250
Elongation in 2-in , per cent	$\frac{1,600,000}{\text{Tens. Str.}}$
Elongation in 2-in , per cent—not less than	24
Reduction of area per cent	$\frac{2,600,000}{\text{Tens. Str.}}$
Reduction of area per cent—not less than	35

The tensile strength shall be reported as information.

S-48. Alternative Tests to Destruction. In the case of orders including only castings not exceeding 150 lb. in weight, a test to destruction of one casting from each 100 castings or smaller lot may be substituted for the tension tests, at the option of the inspector. This test shall show the material to be ductile, free from injurious defects, and suitable for the purpose intended.

S-49. Test Specimens. a Tension-test specimens shall be taken from test bars cast attached to the castings where practicable. If the design of the castings is such that test bars should not be attached to the castings, the test bars shall be cast attached to special blocks of which a sufficient number shall be provided for each lot of castings. Test bars from which tension-test specimens are to be taken shall remain attached to the castings or blocks they represent through heat treatment and until presented for inspection. Test bars shall be provided in sufficient numbers to furnish the tests required.

b If satisfactory to the manufacturer and inspector, tension-test specimens may be cut from heat-treated castings instead of from test bars.

c Tension-test specimens shall conform to dimensions shown in Fig. —. The ends shall be of a form to fit the holders of the testing machine in such a way that the load shall be axial.

d Bend-test specimens shall be machined to 1 in. by $^1/_2$ in. in section with corners rounded to a radius not over $^1/_{16}$ in.

S-50. Number of Tests. a One tension test shall be made from each melt in each treatment charge, and from each casting weighing 500 lb. or over when specified.

b If any test specimen shows defective machining or develops flaws, it may be discarded; in which case another specimen from the same lot shall be substituted.

c If the percentage of elongation of any tension-test specimen is less than that specified and any part of the fracture is more than $^3/_4$ in. from the center of the gage length, as indicated by scribe scratches marked on the specimen before testing, a retest shall be allowed.

S-51. Retreatment. If the results of the physical test for any lot do not meet the requirements specified, such lot may be re-treated, but not more than twice. Retest shall be made as specified.

S-52. Workmanship. Castings shall conform substantially to the shapes and sizes indicated by the patterns and drawings submitted by the purchaser.

S-53. Finish Welding. a Castings shall be free from injurious defects.

b Defects which do not impair the strength of the castings may be welded by an approved process. The defect shall be cleaned out to solid metal, before welding, and when so required by the inspector, shall be submitted to him in this condition for his approval. When required by the inspector, important castings shall be heat treated after welding.

SPECIFICATIONS FOR BOILER RIVET, STAYBOLT, AND REFINED BAR IRON

S-54. Process. The iron shall be rolled from a bloom, slab pile, or box pile made wholly from reworked all-pig puddled iron or reworked knobbled charcoal iron. For rivet and staybolt iron the puddle mixture and the component parts of the bloom, slab pile

or box pile shall be free from any admixture of iron scrap or steel. Staybolt iron shall be double worked, i.e., twice piled.

S-55. Physical Properties and Tests. *a* The iron shall conform to the following requirements as to tensile properties:

	Rivet Iron	Staybolt Iron	Bar Iron
Tensile strength, lb. per sq. in., not over ...	52,000	52,000	53,000
Yield point, lb. per sq. in., not less than	28,000	29,000	28,000
Elongation in 8 in., not less than, Round Section	28 per cent	30 per cent	25 per cent
Reduction of area, not less than, ... Round Section	45 per cent	48 per cent	40 per cent

S-56. Cold-Bend Tests. Rivet Iron. *a* The test specimen shall withstand being bent cold through 180 deg. flat on itself, without fracture on the outside of the bent portion.

Staybolt Iron. *b* The test specimen shall withstand being bent cold through 180 deg. flat on itself in both directions, without fracture on the outside of the bent portions.

Bar Iron. *c* The test specimen shall withstand being bent cold through 180 deg. without fracture on the outside of the bent portion, around a pin the diameter of which is not greater than one-half the square of the thickness or diameter of the specimen.

S-57. Nick-Bend Tests. The test specimen when nicked 25 per cent around for round bars, and along one side for flat bars, with a tool having a 60 deg. cutting edge, to a depth of not less than 8 per cent or more than 16 per cent of the diameter or thickness of the specimen, and broken, shall show a wholly fibrous fracture.

Bend tests may be made by pressure or by blows.

S-58. Etch Tests. The cross-section of the test specimen shall be ground or polished, and etched for a sufficient period to develop the structure. For rivet and staybolt iron this test shall show the material to have been rolled from a bloom, slab pile or box pile and to be free from steel; for bar iron the structure shall be uniform and free from steel.

S-59. Test Specimens. Test specimens shall be of the full section of material as rolled.

S-60. Number of Tests. *a* All bars of a given grade and size shall be piled separately, sorted in lots of 100 each. Two bars shall be selected at random from each lot or fraction thereof and tested as specified; but only one of these bars shall be etch-tested.

b If any test specimen from bars originally selected to represent a lot of material contains surface defects not visible before testing but visible after testing, or if a tension-test specimen breaks outside the middle third of the gage length, the individual bar shall be rejected and one retest from a different bar will be allowed.

S-61. Permissible Variations in Gage. The diameter of each bar shall not vary from that specified more than the amount given in the following table:

Diameters, In.	Variations in Diameter: Under, In.	Variations in Diameter: Over, In.	Out of Round, In.
Up to 1/2, inclusive	0.007	0.007	0.010
Over 1/2 to 1, inclusive	0.010	0.010	0.013
Over 1 to 1 1/4, inclusive	0.012	0.012	0.016
Over 1 1/4 to 1 1/2, inclusive	0.015	0.015	0.021
Over 1 1/2 to 2, inclusive	0.022	0.022	0.023
Over 2 to 2 1/2, inclusive	1/64	3/64	0.023
Over 2 1/2 to 3, inclusive	1/32	3/64	0.035

The widths or thicknesses of flat bars shall not vary more than one per cent from that specified.

S-62. Finish. The bars shall be smoothly rolled and free from slivers, depressions, crop ends, seams and evidences of being burnt.

S-63. Marking. The bars shall be stamped or otherwise marked as designated by the purchaser.

SPECIFICATIONS FOR LAP-WELDED AND SEAMLESS STEEL AND LAP-WELDED IRON BOILER TUBES

Based upon A.S.T.M. Specifications A83–22T

(Comprises Pars. S-64–S-80)

SPECIFICATIONS FOR GRAY-IRON CASTINGS

Based upon A.S.T.M Specifications A48–18

(Comprises Pars. S-81–S-90)

SPECIFICATIONS FOR MALLEABLE CASTINGS

Based upon A.S.T.M. Specifications A47–19 Revised

(Comprises Pars. S-91–S-98)

SPECIFICATIONS FOR COPPER PLATES

Based upon A.S.T.M. Specifications B11–18

(Comprises Pars. S-99–S-109)

SPECIFICATIONS FOR COPPER BARS FOR STAYBOLTS

Based upon A.S.T.M Specifications B12–21

(Comprises Pars. S-110–S-120)

SPECIFICATIONS FOR SEAMLESS COPPER BOILER TUBES

Based upon A.S.T.M. Specifications B13–18

(Comprises Pars. S-121–S-136)

Recent Developments in Balancing Machines

(Continued from page 355)

its synchronous speed. The armature to be balanced is driven by the belt *O*. The critical speed of the apparatus is about 1700 r.p.m. The speed of the armature while operating is 10,000 r.p.m.

The operation of this balancing machine is as follows: The armature is mounted in the machine and the carriage *E* is moved so that the pointer *S* is in one of the transverse planes in which the unbalance is to be corrected. The treadle *R* is pressed down, thus closing the switch *P* and releasing the brake *Q*. The rotation of the armature produces vibrations of the bed around the fulcrum axis; the amplitude is a measure of the weight to be applied at

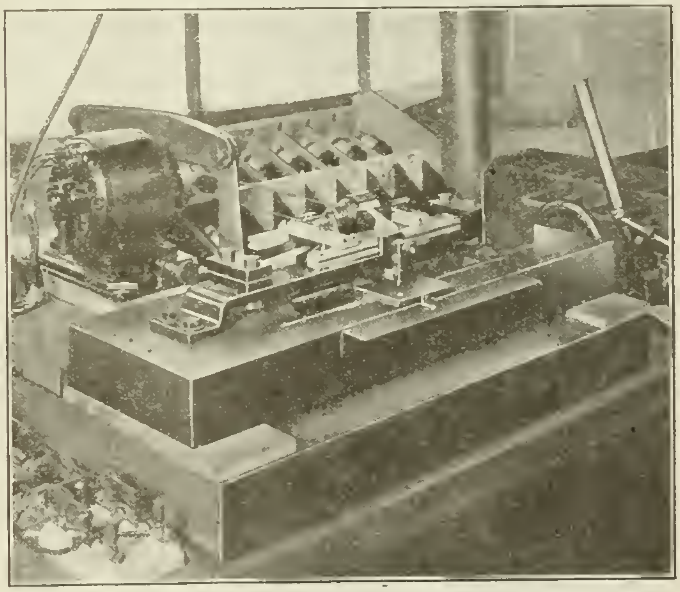

Fig. 6 Balancing Machine Slightly Modified

the other end of the armature. This weight is recorded by the vibrating reed. The treadle is then released, stopping the driving motor almost instantaneously. The recorded weight is applied at an arbitrary location and the armature is again rotated. The second amplitude will indicate if this arbitrary location is correct or not. Three to four trials usually locate the weight correctly. The carriage is then moved into the plane where the first weight was applied and the same procedure is repeated. The entire operation consumes but a few moments.

Fig. 6 shows the same machine slightly modified. The vibrating reed is attached to one end of the vibrating bed. As a result of this, the reed does not record the angular deflection of the bed in a uniform measure for all fulcrum locations. This variation was found to be negligible, however. The production of this machine is about 20 armatures per hour at the present time. It may be increased considerably as the operator gains in experience. The accuracy of the balancing result is ±0.00008 lb. at 3/4 in. radius, the two balancing planes being 1 in. apart.

Safety Code for Mechanical Power-Transmission Apparatus

A Code Now Proposed for General Adoption by the Industrial Accident Boards and Commissions of the Various States

In the November, 1920, issue of "Mechanical Engineering" the formation of a Sectional Committee to develop a national Safety Code for Mechanical Power-Transmission Apparatus was announced. This committee was organized under the Rules of Procedure of the American Engineering Standards Committee and has for its sponsors the International Association of Industrial Accident Boards and Commissions, The National Workmen's Compensation Service Bureau, and The American Society of Mechanical Engineers.

During the progress of the Sectional Committee's work a number of drafts of the code were prepared and passed upon by its 24 members. Later printed proofs were circulated to approximately 400 persons known to be interested in the development of this code. These included manufactures of this equipment, users of the equipment, and safety-code enforcement officers.

All the comments offered as a result of this circularization were carefully considered at a meeting of the full Sectional Committee and a revised draft of the code was subsequently prepared. This revised draft has now been formally presented to the three sponsor bodies for approval and adoption, actions which are obviously necessary before this safety code can be transmitted to the American Engineering Standards Committee for approval as a Tentative American Standard.

The following abstract of this code was prepared at the request of the A.S.M.E. Standing Committee on Safety Codes by Carl B. Auel, one of its members who is also one of that society's representatives on this Sectional Committee and is serving as its chairman.

The Safety Code for Mechanical Power-Transmission Apparatus, as it now stands, is the result of a very considerable amount of study over a period of many months. The Committee did not rely alone upon the judgment of its members, but had as well the benefit of the advice and experience of many experts, who willingly placed themselves at the service of the Committee in various ways.

Following the trend of more recent efforts in safety work, the code is an endeavor to combine the best, both with respect to theory and to practice; and, where these seemed occasionally at variance, decision was reached only after careful consideration as to which should be followed.

It is therefore reasonable to assume that while the code, as time goes on, unquestionably will undergo modification and improvement, it nevertheless in its present form offers adequate protection to the workers in industry.

Scope

This code applies to all moving parts of equipment used in the mechanical transmission of power, including prime movers, intermediate equipment and driven machines, excluding point of operation.

Note: The safeguarding of all connecting rods, cranks, flywheels, shafting, spindles, pulleys, belts (except flat belts one (1) inch or less in width or round belts one-half (½) inch or less in diameter), link belts, chains, ropes and rope drives, gears, sprockets, friction drives, cams, couplings, clutches, counterweights, revolving or reciprocating parts, up to but not including point of operation, also all bolts, keys, set screws, oil cups or similar projections, shall be included in and be in accordance with the provisions of the Mechanical Power-Transmission Code.

Interpretations and Exceptions

The purpose of this code is to provide reasonable safety for life, limb, and health. It should be liberally construed and applied by enforcing authorities to secure these results and in cases of practical difficulty or unnecessary hardship, exceptions from the literal requirements may be granted so long as equivalent protection is secured. Where specific devices or methods are mentioned in this code, other devices or methods which will secure equally good results may be used, subject to the approval of the enforcing authority.

Definitions

In order to clarify the text, it is prefaced by definitions of a number of the terms used; as, for example, the term "exposed to contact" is "interpreted as meaning that the location of any object is such that a person is liable to come into contact with it and be injured."

The code itself is divided into six parts, each with suitable subdivisions. These parts have to do respectively with prime movers, mechanical power-transmission equipment, starting and stopping devices, guard standards, operating rules, and discussion.

Prime Movers

This part of the code is very brief and offers no complications in the carrying out of its requirements, concerning itself simply with the guarding of flywheels, cranks, connecting rods, tail rods, and governor balls. As will be observed in this section, and, in fact, largely throughout the code, alternative methods of guarding have been presented wherever possible.

Flywheels located so that any part is six (6) feet or less above floor or platform shall be guarded in one of the following ways:

(*a*) With an inclosure of sheet, perforated, or expanded metal or woven wire.

(*b*) With guard rails placed not less than fifteen (15) inches nor more than twenty (20) inches from rim. When flywheel extends into pit or is within 12 inches of floor a standard toe board shall also be provided.

(*c*) When the upper rim of flywheel protrudes through a working floor it shall be entirely enclosed or surrounded by a guard rail and toe board.

(*d*) For flywheels with smooth rims five (5) feet or less in diameter, where the preceding methods cannot be applied, the following may be used: A disk attached to the flywheel in such manner as to cover the spokes of the wheel on the exposed side and present a smooth surface and edge, at the same time providing means for periodic inspection. An open space, not exceeding four (4) inches in width may be left between the outside edge of the disk and the rim of the wheel if desired, to facilitate turning the wheel over. Where a disk is used, the keys or other dangerous projections not covered by disk, shall be cut off or covered.

Note: This does not apply to flywheels with solid web centers.

(*e*) Adjustable guard to be used for starting engine or for running adjustment may be provided at the flywheel of gas or oil engines. A slot opening for jack bar will be permitted.

Cranks and connecting rods, when exposed to contact, shall be guarded in accordance with Part IV, Sections 40 and 41, or by a guard rail as described in Part IV, Rule 424.

Tail rods or extension piston rods shall be guarded in accordance with Part IV, Sections 40 and 42, or by a guard rail on sides and end, with a clearance of not less than fifteen (15) inches when rod is fully extended.

Governor balls six (6) feet or less from the floor or other working level, when exposed to contact, shall be provided with an enclosure extending to the top of the governor balls when at their highest position.

Mechanical Power-Transmission Equipment

As would be expected, this section, having to do with transmission equipment, constitutes the backbone of the code, shafting, pulleys, belts, ropes, gears, sprockets, chains, friction drives, keys and other projections, collars, couplings, and bearings, being treated in turn.

Shafting. Additional to the necessity of thoroughly guarding all exposed shafting when six feet or less from the floor or working platform, or unless at least fifteen feet above a driveway, particular emphasis is placed on the need for securing shafting, whether horizontal, vertical, or inclined, against excessive endwise movement.

Projecting shafting ends are not permitted, except when guarded by non-rotating caps or safety sleeves.

It is realized that the guarding of shafting in the regulation manner would involve an unnecessary expense if the rules were made universally mandatory. Exception has therefore been made in the case of shafting located in basements, used exclusively for power-transmission equipment, by the following provisions:

When belts, pulleys, and shafting are located in basements, towers, and rooms used exclusively for power-transmission equipment, the requirements for safeguarding may be waived if the following conditions are met:

1 The basement, tower, or room occupied by transmission equipment shall be locked against unauthorized entrance.

2 The vertical clearance in passageways between the floor and power-transmission beams, ceiling or any other objects, should not be less than five (5) feet six (6) inches.

3 The intensity of illumination shall conform to The American Engineering Standards Code for lighting of factories, mills, and other work places.

4 The footing shall be dry, firm, and level.

5 The route followed by the oiler shall be protected in such a manner as to prevent accident.

Pulleys. Pulleys are required to be guarded if any parts are six feet or less from the floor or working platform; but modification is made in this requirement when they serve as balance wheels, for example on punch presses, the code providing that:

Pulleys any part of which are six (6) feet or less from the floor or working platform shall be guarded in accordance with the standards specified under Part IV, Sections 40 and 42. Pulleys serving as balance wheels (e.g., punch presses) on which the point of contact between belt and pulley is more than six (6) feet from the floor or platform, may be guarded with a disk covering the spokes.

Guides are required to prevent belts leaving pulleys, unless the distance to the nearest fixed pulley, clutch, or hanger exceeds the width of the belt used. Overhanging pulleys, where there is no bearing between them and the outer end of the shafting, must be similarly provided with guides.

The use of pulleys with cracked or broken rims is forbidden, as in the use of composition or wood pulleys in locations where they would be subjected continually to the action of moisture.

Particular warning is given against operating pulleys at excessive speeds as follows:

Pulleys operating at a rim speed in excess of 4000 feet per minute shall be especially designed for the purpose and carefully balanced for the speed at which they are to operate.

Belts, Ropes, and Chain Drives. In the guarding of belts and ropes, the code states:

(*a*) Where both runs of horizontal belts are six (6) feet or less from the floor level, the guard shall extend to at least fifteen (15) inches above the belt or to a standard height except that where both runs of a horizontal belt are 42 inches or less from the floor, the belt shall be fully enclosed in accordance with Part IV, Sections 40 and 42.

Note: In power plants or power-development rooms a guard rail may be used in lieu of the above.

(*b*) Overhead horizontal belts, with lower part seven (7) feet or less from the floor or platform, shall be guarded on sides and bottom.

(*c*) Horizontal overhead belts more than seven (7) feet above floor or platform shall be guarded for their entire length under the following conditions.

1 If located over passageways or work place and traveling 1800 feet or more per minute, and

2 If center to center distance between pulleys is ten (10) feet or more, and

3 If belt is eight (8) inches or more in width.

For exception in case of flat belts 1 inch or less in width or round belts 1/2 inch, or less in diameter, see "Scope."

(*d*) Where the upper and lower runs of horizontal belts are so located that passage of persons between them would be possible the passage shall be either:

1 Completely barred by a guard rail or other barrier in accordance with Part IV, Sections 40 and 42.

2 Where passage is regarded as necessary there shall be a platform over the lower run guarded on either side by a railing completely filled in with wire mesh or other filler or by a solid barrier. The upper run shall be so guarded as to prevent contact therewith either by the worker or by objects carried by him.

In power plants only the lower run of the belt need be guarded.

(*e*) Overhead chain and link-belt drives, where the chain exceeds two (2) inches in width, are governed by the same rules as overhead horizontal belts and shall be guarded in the same manner as belts.

(*f*) American or Continuous System rope drives so located that the condition of the rope (particularly the splice) cannot be constantly and conveniently observed, shall be equppied with a "tell-tale" device (preferably electric-bell type) that will give warning when rope begins to fray.

(*a*) Vertical and inclined belts shall be enclosed by a guard conforming to standards in Part IV, Sections 40 and 42.

(*b*) All guards for inclined belts shall be arranged in such a manner that a minimum clearance of six (6) feet six (6) inches is maintained between belt and floor at any point outside of guard.

Vertical belts running over a lower pulley more than six (6) feet above floor or platform shall be guarded at the bottom in the same manner as horizontal overhead belts if conditions are such as stated in Rule 220-*c*, 1 and 3.

A cone-pulley drive with all parts of the lower cone pulley three (3) feet or more above the floor need not be guarded. Where any part of the lower cone pulley is less than three (3) feet from the floor, the pulley and belt shall be guarded in accordance with Part IV, Sections 40 and 42.

Gears, sprockets, and chains are to be guarded in accordance with the following specifications:

(*a*) A complete enclosure.

(*b*) A standard guard six (6) feet high extending six (6) inches above the mesh point of the gears.

(*c*) By a band guard covering the face of gear and having flanges extended inward beyond the root of the teeth on the exposed side or sides. Where any portion of the train of gears guarded by a band guard is less than six (6) feet from the floor a disk guard or a complete enclosure to the height of six (6) feet shall be required.

All sprocket wheels and chains shall be enclosed unless more than seven (7) feet above the floor or platform.

When frequent oiling must be done, openings with hinged or sliding self-closing covers shall be provided.

Friction Drives. Friction drives are treated much like gears:

(*a*) The driving point of all friction drives when exposed to contact shall be guarded.

(*b*) All arm or spoke friction drives and all web friction drives with holes in the web shall be entirely enclosed.

(*c*) All projecting bolts on fraction drives where exposed to contact shall be guarded.

Keys, Set Screws, Etc. The code states that:

All projecting keys, set screws, and other projections in revolving parts shall be removed or made flush or guarded by metal cover. This does not apply to keys or set screws within gear or sprocket casings or other enclosures, nor to keys, set screws or oil cups in hubs of pulleys where they are within the plane of the rim of the pulley.

It is further recommended that no projecting set screws or oil cups be used in any revolving pulley or part of machinery, even though they are within the limits stated in the above paragraph.

Collars and Couplings. Collars and couplings are required to be cylindrical in shape, and screws or bolts used in them must present no hazard.

Starting and Stopping Devices

Under this section are treated clutches, cut-off couplings, clutch pulleys, belt shifters, shippers, poles, perches, and fasteners.

Regarding the first of these items, the code provides that:

(*a*) Clutches, cut-off couplings or clutch pulleys having projecting parts, where such clutches are located seven (7) feet or less above the floor or working platform, shall be enclosed by a stationary guard constructed in accordance with these standards (the "U" type guard is permissible).

Note 1: Where clutches, cut-off couplings, or clutch pulleys are so situated within a machine or otherwise guarded by location, the application of this rule is within the discretion of the enforcing authority.

Note 2: In engine rooms a guard rail, preferably with toe board, will be permitted instead of the above, provided this room is occupied only by engine-room attendants.

Note 3: The use of a bearing support immediately adjacent to a friction clutch or cut-off coupling being recognized engineering practice, only self-lubricating bearings requiring attention at infrequent intervals shall be used in such locations.

An excellent caution in connection with belt and clutch shifters is contained in the following provision:

(*c*) All belt and clutch shifters of the same type in each shop should move in the same direction to stop machines, i.e., either all *right* or all *left*.

Belt shippers and poles are not recommended, nor are belt perches.

Perhaps no part of the code received greater attention than did belt fasteners, and a considerable number of belting experts, more particularly manufacturers of canvass and rubber belting, were invited to discuss this matter at a special meeting of the Committee. The following provision was finally adopted:

Belts which of necessity must be shifted by hand and belts within six (6) feet of the floor or working platform which are not guarded in accordance with the intent of this code shall not be fastened with metal in any case nor with any other fastening which by construction or wear will constitute an accident hazard.

Guard Standards

Under this section has been included materials for guard construction, designs of guards, and methods of manufacture.

Expanded metal, perforated or solid sheet metal, and wire mesh on a metal frame have been fixed as the standard materials for guard construction.

(*a*) Standard conditions will be secured by the use of the following materials: Expanded metal, perforated or solid sheet metal or wire mesh on a frame of angle iron or iron pipe securely fastened to floor or to frame of machine.

(*b*) All metal should be free from burrs and sharp edges.

(*c*) Wire mesh should be of the type in which the wires are securely fastened at every cross point either by welding, soldering or galvanizing, except in case of diamond or square wire mesh made of No. 14 gage wire, 3/4-in. mesh or heavier.

In the design of guards emphasis is placed on the desirability of making them with hinged sections or removable, where it is necessary to change belts, make adjustments, or oil parts.

Considerable space has been given to details of guard manufacture with information as to sizes of materials, clearances, etc. Illustrations are also used.

The code closes with a few of the more important rules in the care and operation of equipment and a brief discussion of the reasons leading to the adoption of certain features.

ENGINEERING RESEARCH

A Department Conducted by the Research Committee of the A.S.M.E.

Résumé of the Month

A—Research Results

The purpose of this section of Engineering Research is to give the origin of research information which has been completed, to give a résumé of research results with formulas or curves where such may be readily given, and to report results of non-extensive researches which in the opinion of the investigators do not warrant a paper.

Fuels A3-23. How Steam Production Costs were Reduced in a Hand-Fired Return-Tubular Boiler Plant. See *Steam Power A1-23.*

Fuels A4-23. Value of Coke, Anthracite, and Bituminous Coal for Generating Steam in a Low-Pressure Cast-Iron Boiler. A series of steaming tests recently made at the Pittsburgh experiment station of the Bureau of Mines are described in a pamphlet known as Technical Paper No. 303. This paper was prepared by Messrs. John Blizard, James Neil, and F. C. Houghten.

The primary purpose of the tests was to determine the relative steaming values of coke, anthracite, and bituminous coal when burned in a low-pressure boiler, and fired by hand in fairly large quantities at a time.

A secondary purpose of the tests was to separate the heat losses, and to examine them carefully to determine the change in efficiency with the method of firing the fuel and manipulation of the draft dampers, with the rate of evaporation, and with the various fuels burned.

Other purposes may be mentioned, such as determination of the draft used, temperatures and composition of the gases in the flues, furnace, and combustion chamber, and other factors affecting the operation of the boiler.

Before these tests were completed, some special tests were run at the request of the Chamber of Commerce of Pittsburgh, to compare the steaming value and smoke emission of mixtures of coke breeze and Pittsburgh coal with those of the latter alone; results of these tests are also embodied in this report.

Address the Superintendent of Documents, Government Printing Office, Washington, D. C. Price per copy, 10 cents.

Industrial Management A1-23. How Steam Production Costs were Reduced in a Hand-Fired Return-Tubular Boiler Plant. See *Steam Power A1-23.*

Instruments and Apparatus A1-23. Testing of Barometers and Altimeters. This Circular of the Bureau of Standards, No. 46, describes the testing of mercurial and aneroid barometers at the Bureau and announces the fees which are charged for the various tests.

Address the Superintendent of Documents, Government Printing Office, Washington, D. C. Price per copy, 10 cents.

Machine Tools A1-23. Lathe Breakdown Tests of Some High-Speed Tool Steels. This report known as Technologic Paper No. 228 was prepared by H. J. French of the Bureau of Standards and Jerome Strauss of the U. S. Naval Gun Factory. In it, comparative lathe cutting tests are reported for about 25 brands, representing various compositions.

Important conclusions drawn from the described tests may be summarized as follows:

1 Breakdown tests, in which endurance of tools is determined under definite working conditions, are not satisfactory as the basis of purchase for high-speed tool steels.

2 In certain severe breakdown tests with roughing tools on 3 per cent nickel-steel forgings, in which high frictional temperatures were produced, it was found that the performance of commercial low-tungsten-high-vanadium and cobalt steels was superior to that of the high-tungsten-low-vanadium type and special steels containing about $1/4$ per cent uranium or $3/4$ per cent molybdenum. The average power consumption in all cases was practically the same.

3 Modification in test conditions, including small changes in tool angles but principally changes in cutting speed, more markedly affected the performance of steels containing cobalt or special elements, such as uranium or molybdenum, than that of the basic types (plain chromium-tungsten-vanadium steels).

4 The relatively poor endurance of the high-tungsten steels under severe working conditions was not observed in more moderate tests, made on the same test log with equal cutting speed and depth of cut but with reduced feed, in which the frictional temperatures produced were not so high. Also in these latter tests the performance of the cobalt steels was better than either the low- or high-tungsten steels.

5 Hardness determinations and examination of fractures indicate that the various types of commercial high-speed steel show differences in behavior under heat treatment and in physical properties which probably are of importance under moderate working conditions and might counterbalance slight advantages in performance.

The paper contains fifteen tables. Address the Superintendent of Documents, Government Printing Office, Washington, D. C.

Non-Ferrous Metals A4-23. Solders for Aluminum. Most of the metals commonly used in solders, except magnesium, are electropositive to aluminum, so that any metals used in making a soldered joint of aluminum act electrolytically in the presence of moisture accelerating the corrosion of the aluminum. Magnesium cannot be utilized because it disintegrates rapidly in the presence of moisture. Soldered joints of aluminum exposed to moisture should be protected by paint or varnish. Various compositions of zinc-tin and zinc-tin-aluminum solders give the best results. The tensile strength of a good aluminum solder is about 7000 lb. per sq. in. Those with higher tensile strength usually have such a high temperature of complete liquidation that they are unsuited for soldering purposes.

Circular No. 78 of the Bureau of Standards entitled, Solders for Aluminum, has recently been revised. It will soon be available from the Superintendent of Documents, Government Printing Office, Washington, D. C., at 5 cents a copy.

Steam Power A1-23. How Steam Production Costs were Reduced in a Hand-Fired Return-Tubular Boiler Plant. During the course of an investigation conducted by the fuel section of the Bureau of Mines, on a hand-fired return-tubular boiler plant, it was found that the average cost of fuel to produce 1000 lb. of steam was \$0.5287. Tests conducted after some simple changes had been made in the furnaces, and in the control of the boilers, showed the previous high cost of fuel per 1000 lb. of steam could be reduced to the reasonable figure of \$0.3540, or the equivalent of over 30 per cent saving in fuel cost.

These tests were made by A. R. Mumford, assistant fuel engineer of the Bureau of Mines, and consisted of a comparative study in the use of pea-size anthracite and bituminous coal without smoke. They involved experimental modifications of the setting, modifications in the method of control of the boilers, and improvement in the methods of firing. This last resolved itself into a comparative time study.

The total savings shown possible by the modifications introduced are approximately 900 tons of coal in an eleven-month period, and approximately \$12,500 in total fuel cost. Reports of Investigations, Serial No. 2455, U. S. Bureau of Mines, Washington, D. C.

Steel, Its Treatment and Products A1-23. Lathe Breakdown Tests of Some High-Speed Tool Steels. See *Machine Tools A1-23.*

B—Research in Progress

The purpose of this section of Engineering Research is to bring together those who are working on the same problem for coöperation or conference, to prevent unnecessary duplication of work, and to inform the profession of the investigators who are engaged upon research problems. The addresses of these investigators are given for the purpose of correspondence.

Instruments and Apparatus B2-23. Saybolt Universal Viscosimeter. A conference was held at the Bureau of Standards, November 14 with members of the American Petroleum Institute, as a result of which a committee of 5 members of the Institute was appointed to coöperate with the Bureau in expediting the more accurate standardization of the Saybolt universal viscosimeter.

The Institute and the Bureau are also coöperating with the Society of Automotive Engineers and the Interdepartmental Committee on Petroleum Products in the development of a numbering system for lubricating oils based on their viscosity.

Iron and Steel B1-23. Wear Tests of Steel. An investigation of the resistance to wear of steels has been in process at the Bureau of Standards for some time. During the past month a study has been made of the effect of keeping the surfaces of the specimens clean and free from all adhering abraded particles. A cloth buffing wheel, rotated at high speed by electric motor, has been used successfully for this purpose. It has been found that when the wearing surfaces are thus kept free of abraded metallic dust, the rate of wear drops to an almost negligible quantity compared with the rate when the wearing surfaces are not kept clean by the buffing wheel. Address Dr. Geo. K. Burgess, Director of the Bureau of Standards, Washington, D. C.

Lubricants B1-23. Saybolt Universal Viscosimeter. See *Instruments and Apparatus B2-23.*

Non-Ferrous Metals B2-23. Gases in Monel Metal. The Bureau of Standards has just completed determinations of oxygen and hydrogen in samples representing three phases of the deoxidation of monel metal. The samples were all from 50-lb. blocks cast during the progress of a regular heat. These samples represent (1) the metal at the time of tapping the furnace before the addition of any deoxidizers; (2) the above metal after the addition of ferro manganese in the ladel, and (3) the above metal after the further addition of magnesium in the ladle, that is, after all additions have been made. Both oxygen and hydrogen in the metal decreased rapidly with the progress of deoxidation. The finished metal, as represented by the last sample of this heat and

by samples of completely deoxidized metal from two other heats, contains from 0.002 to 0.005 per cent oxygen. All samples appear rather porous under a magnification of 100.

A sample of monel metal prepared as above, except that a portion of the deoxidation was carried out in the furnace rather than entirely in the ladle, showed no porosity, and no oxygen could be detected. A sample of monel metal from a Herault furnace heat, which had been completely deoxidized in the furnace, likewise was entirely sound and contained no oxygen. Of the five samples of finished monel metal examined the three which were deoxidized by addition of ferromanganese and magnesium in the ladle were porous and contained from 0.002 to 0.005 per cent oxygen, while the two which were deoxidized entirely or in part in the furnace were sound and contained no oxygen.

Paper B1-23. THE TENSILE STRENGTH OF PAPER. There are a number of devices for determining the tensile or breaking strength of paper, but the procedure in carrying out the tests has not been standardized; thus all sorts of combinations of width and length of the test specimen, rate of applying the load, and time during which the specimen is under stress, are in use.

A study of these various factors recently completed by the Bureau of Standards indicates that there is considerable difference in the amount of stretch when the factors are varied, but when only the strength is to be considered, the length of the specimen, within limits, is of negligible importance, while the strength is almost proportional to the width.

Paper B2-23. THE MULLEN TESTER FOR MEASURING THE QUALITY OF PAPER. What is known as the Mullen tester is used almost universally in this country for determining the bursting strength of paper, and on this factor is based to a large extent the measure of the quality of the paper. It often happens, however, that a sheet may be so made or so sized as to have a very high bursting strength and yet show up very poorly in a tearing or folding test.

The Bureau of Standards is working on a supplementary test employing two steel rollers which produce a crease in the paper under controlled conditions of pressure and time. The bursting strength is determined before and after such folding. The loss of strength under these conditions is an excellent indication of the brittleness of the paper. The method, however, must still be standardized. A report on this subject will be published in the near future.

Rope B1-23. TESTS FOR NEW DESIGN OF LARGE HAWSERS. Tensile tests were made during the past month at the Bureau of Standards on twenty-one samples of very large hawsers. The purpose of these tests was to determine the comparative strength of a new type of construction for manila rope as compared with the standard method of construction. In the new type the inner yarns of the strands are untwisted. The strands are made up of several outer layers of twisted yarns binding this inner compact mass of fibers; these strands being twisted in the usual manner to form the rope. The tests showed that in all cases the new type of construction increases the strength of the rope.

Steel, Its Treatment and Products B1-23. CARBURIZATION OF STEEL. An investigation of the effect of the quality of steel upon its carburizing properties, and particularly its hardening properties after carburization, was suggested to the Bureau of Standards by metallurgists as a problem of very considerable commercial importance. As soon as the necessary material (abnormal steels) can be obtained, the work will be started.

F—BIBLIOGRAPHIES

The purpose of this section of Engineering Research is to inform the profession of bibliographies which have been prepared. In general this work is done at the expense of the Society. Extensive bibliographies require the approval of the Research Committee. All bibliographies are loaned for a period of one month only. Additional copies are available, however, for periods of two weeks to members of the A.S.M.E. These bibliographies are on file at the headquarters of the Society.

Heat Transmission F1-23. HEAT EXCHANGERS. A bibliography consisting of two pages. Search No. 3717. Address the A.S.M.E., 29 West 39th Street, N. Y. C.

Machine Design F1-23. RING-OILING SYSTEMS. A bibliography consisting of one page. Search No. S 3683. Address the A.S.M.E., 29 West 39th Street, N. Y. C.

CORRESPONDENCE

CONTRIBUTIONS to the Correspondence Department of MECHANICAL ENGINEERING are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities and policies of the Society in Research and Standardization.

Methods of Calculating the Diameters of Open-Belt Speed Cones

TO THE EDITOR:

The following is submitted as a rational method for calculating the radii of open-belt speed cones.

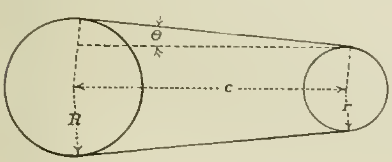

FIG. 1 DIAGRAM OF OPEN-BELT DRIVE

Let L = length of belt
c = distance between pulley centers
r = radius of smaller pulley
k = velocity ratio, whence
$R = kr$ = radius of larger pulley.

Then, referring to Fig. 1,

$$L = 2c\cos\theta + r(\pi - 2\theta) + kr(\pi + 2\theta)$$

$$= 2c\frac{\sqrt{c^2 - r^2(k-1)^2}}{c} + \pi r(k+1) + r(k-1)2\theta$$

$$= 2c\sqrt{1 - \left[\frac{r(k-1)}{c}\right]^2} + 2c\left(\frac{\pi}{2}\ \frac{k+1}{k-1}\right)\frac{r(k-1)}{c}$$

$$+ 2c\frac{r(k-1)}{c}\sin^{-1}\frac{r(k-1)}{c}$$

Let $\frac{r(k-1)}{c} = u$; then, substituting in the preceding equation,

$$\frac{L}{2c} = \left[1 + (-u^2)\right]^{\frac{1}{2}} + \left(\frac{\pi}{2}\ \frac{k+1}{k-1}\right)u + u\sin^{-1}u$$

$$= 1 + \frac{1}{2}(-u^2) + \frac{\frac{1}{2}\left(-\frac{1}{2}\right)(-u^2)^2}{\underline{|2}}$$

$$+ \frac{\frac{1}{2}\left(-\frac{1}{2}\right)\left(-\frac{3}{2}\right)(-u^2)^3}{\underline{|3}}$$

$$+ \frac{\frac{1}{2}\left(-\frac{1}{2}\right)\left(-\frac{3}{2}\right)\left(-\frac{5}{2}\right)(-u^2)^4}{\underline{|4}} + \cdots$$

$$+ \left(\frac{\pi}{2}\ \frac{k+1}{k-1}\right)u$$

$$+ u\left[u + \frac{u^3}{2\cdot 3} + \frac{3u^5}{2\cdot 4\cdot 5} + \frac{3.5u^7}{2\cdot 4\cdot 6\cdot 7} + \frac{3.5.7u^9}{2\cdot 4\cdot 6\cdot 8\cdot 9} + \cdots\right]$$

or

$$\frac{L}{2c} - 1 = \left(\frac{\pi}{2}\ \frac{k+1}{k-1}\right)u + \frac{1}{2}u^2$$

$$+ \frac{1}{24}u^4 + \frac{1}{80}u^6 + \frac{5}{896}u^8 + \frac{7}{2304}u^{10} + \cdots$$

Let $\frac{L}{2c} - 1 = V$ and

$$u = AV + BV^2 + CV^3 + DV^4 + EV^5 + FV^6 + \cdots$$

Substituting the series in u for V in the series in V gives

$$u = A\left(\frac{\pi}{2}\ \frac{k+1}{k-1}\right) u + A\,\frac{1}{2}\,u^2 + A\,\frac{1}{24}\,u^4 \ + \ + A\,\frac{1}{80}\,u^6 + \cdots$$
$$+ B\left(\frac{\pi}{2}\ \frac{k+1}{k-1}\right) u^2 + B\left(\frac{\pi}{2}\ \frac{k+1}{k-1}\right) u^3 + B\,\frac{1}{4}\,u^4$$
$$+ B\,\frac{1}{24}\left(\frac{\pi}{2}\ \frac{k+1}{k-1}\right) u^5 + \cdots$$
$$+ C\left(\frac{\pi}{2}\ \frac{k+1}{k-1}\right)^3 u^3 + C\,\frac{3}{2}\left(\frac{\pi}{2}\ \frac{k+1}{k-1}\right)^2 u^4$$
$$+ C\,\frac{3}{4}\left(\frac{\pi}{2}\ \frac{k+1}{k-1}\right) u^5 + \cdots$$
$$+ D\left(\frac{\pi}{2}\ \frac{k+1}{k-1}\right)^4 u^4 + D\,\frac{3}{2}\left(\frac{\pi}{2}\ \frac{k+1}{k-1}\right)^3 u^5 + \cdots$$
$$+ E\left(\frac{\pi}{2}\ \frac{k+1}{k-1}\right)^5 u^5 + \cdots$$

Equating like coefficients,

$$A = \left(\frac{2}{\pi}\ \frac{k-1}{k+1}\right) \qquad B = -\frac{1}{2}\left(\frac{2}{\pi}\ \frac{k-1}{k+1}\right)^3$$

$$C = \frac{1}{2}\left(\frac{2}{\pi}\ \frac{k-1}{k+1}\right)^5$$

$$D = \left[\frac{1}{24}\left(\frac{2}{\pi}\ \frac{k-1}{k+1}\right)^5 + \frac{5}{8}\left(\frac{2}{\pi}\ \frac{k-1}{k+1}\right)^7\right]$$

$$E = \frac{1}{48}\left(\frac{2}{\pi}\ \frac{k-1}{k+1}\right)^9 - \frac{3}{8}\left(\frac{2}{\pi}\ \frac{k-1}{k+1}\right)^{11}$$
$$+ \frac{3}{48}\left(\frac{2}{\pi}\ \frac{k-1}{k+1}\right)^{13} + \frac{15}{16}\left(\frac{2}{\pi}\ \frac{k-1}{k+1}\right)^{15}$$

$$F = -\left[\frac{1}{80}\left(\frac{2}{\pi}\ \frac{k-1}{k+1}\right)^7 - \frac{1}{48}\left(\frac{2}{\pi}\ \frac{k-1}{k+1}\right)^9\right.$$
$$+ \frac{1}{16}\left(\frac{2}{\pi}\ \frac{k-1}{k+1}\right)^{11} + \frac{5}{96}\left(\frac{2}{\pi}\ \frac{k-1}{k+1}\right)^{15} - \frac{15}{16}\left(\frac{2}{\pi}\ \frac{k-1}{k+1}\right)^{17}$$
$$\left. + \frac{15}{96}\left(\frac{2}{\pi}\ \frac{k-1}{k+1}\right)^{19} + \frac{75}{32}\left(\frac{2}{\pi}\ \frac{k-1}{k+1}\right)^{21}\right]$$

Substituting these values in

$$u = AV + BV^2 + CV^3 + DV^4 + EV^5 + FV^6 + \cdots$$

where $u = \dfrac{r(k-1)}{c}$ and $V = \dfrac{L}{2c} - 1$, and letting $\dfrac{2}{\pi}\ \dfrac{k-1}{k+1} = w$,

$$r = \frac{c}{k-1}\left[wV - \frac{1}{2}w^3V^2 + \frac{1}{2}w^5V^3 - \left(\frac{1}{24}w^5 - \frac{5}{8}w^7\right)V^4\right.$$
$$+ \left(\frac{1}{48}w^9 - \frac{3}{8}w^{11} + \frac{3}{48}w^{13} + \frac{15}{16}w^{51}\right)V^5 - \left(\frac{1}{80}w^7 - \frac{1}{48}w^9\right.$$
$$\left. + \frac{1}{16}w^{11} + \frac{5}{96}w^{15} - \frac{15}{16}w^{17} + \frac{15}{96}w^{19} + \frac{75}{32}w^{21}\right)V^6 + \cdots\Big]$$

If $k = 1$, this equation reduces to

$$r = \frac{1}{\pi}\left(\frac{L}{2} - c\right)$$

The values of r given by this series may be calculated to any desired degree of accuracy by taking a large enough number of terms.

For values of angle θ up to four or five degrees the series converges very rapidly; the rapidity of convergence falling off, however, as the belt angle is increased.

The first two or three terms will generally be sufficient for cases with small belt angles; while the fourth should suffice for angles up to and including 10 or 11 deg. for θ.

In using this formula either the belt length should be calculated to fit a pair of pulleys at the start or some convenient belt length should be fixed upon and then the pulleys calculated to fit the belt.

The dimensions L, c, and r must, of course, always be taken in the same units.

W. H. Wise.

Missoula, Mont.

To the Editor:

In a correctly designed speed-cone drive the same belt will work in all positions with equal tightness. This is accomplished by so arranging the sum of the diameters that the length of belt required to pass over each pair of steps will remain constant. By comparing the formula for the exact length of a crossed belt [1] with that for the exact length of an open belt [2], it will be seen that in the former case the length is a function of the center distance and the sum of the diameters, while in the latter the length is a function of the center distance and the sum and difference of the diameters.

$$L = \frac{1}{2}(D+d)\left[\pi + 2\sin^{-1}\frac{D+d}{2c}\right.$$
$$\left. + 2\cot\left(\sin^{-1}\frac{D+d}{2c}\right)\right] \ldots\ldots [1]$$

$$L = \frac{\pi}{2}(D+d) + (D-d)\sin^{-1}\frac{D-d}{2c}$$
$$+ 2\,C\cos\left(\sin^{-1}\frac{D-d}{2c}\right) \ldots\ldots [2]$$

where

D = diameter of the larger pulley
d = diameter of the smaller pulley
c = center distance between shafts, and
L = length of belt.

Therefore, if the belt is to work with equal tightness when crossed, since the center distance is constant it is sufficient to so design the steps that the sum of the diameters of one pair shall equal the sum of the diameters of any other pair. In other words,

$$D_1 + d_1 = D_2 + d_2 = D_3 + d_3, \text{ etc.}$$

In the case of an open belt, however, not only the sum but also the difference of the diameters must be constant; this condition it is impossible to satisfy, hence there can be no direct solution.

Several excellent graphical methods have been devised. In practice, however, it is difficult to make a layout sufficiently accurate; very often the center distance is too long for the equipment on hand, so that a layout must be made to a small scale, and a very slight error will greatly affect the final results. None of the theoretical formulas known can be considered a convenient way of solving the problems because of their complexity and length.

The following is the method used by the writer in constructing a logarithmic chart which greatly simplifies the calculations of cone-pulley diameters. The formula for the length of an open belt is given by Professor Unwin as follows:

$$L = \frac{\pi}{2}(D+d) + 2c\left[1 + \frac{(D-d)^2}{8c^2}\right] \ldots\ldots\ldots [3]$$

which is very nearly the exact length. Let D_0 and d_0 be the diameters of one pair and D_1 and d_1 the diameters of any other pair of steps in the same cone; then, the length of the belt being the same,

$$L = \frac{\pi}{2}(D_0 + d_0) + 2c\left[1 + \frac{(D_0 - d_0)^2}{8c^2}\right]$$
$$= \frac{\pi}{2}(D_1 + d_1) + 2c\left[1 + \frac{(D_1 + d_1)^2}{8c^2}\right] \ldots\ldots\ldots\ldots\ldots\ldots [4]$$

Solving for $D_1 + d_1$,

$$D_1 + d_1 = D_0 + d_0 + \frac{(D_0 - d_0)^2 - (D_1 - d_1)^2}{2\,\pi c} \ldots\ldots [5]$$

If D_0 and d_0 be the diameters of a pair selected to give the speed ratio $k = 1$, then $D_0 = d_0$ and $(D_0 - d_0) = 0$. Substituting this value in [5],

$$D_1 + d_1 = D_0 + d_0 - \frac{(D_1 - d_1)^2}{2\pi c} \qquad [6]$$

which means that for open-belt service the sum of the diameters of any pair of pulleys equals the sum of the diameters of a pair of mutually equal pulleys for the ratio $k = 1$ minus a correction (K) whose value is

$$K = \frac{(D_1 - d_1)^2}{2\pi c} \qquad [7]$$

Since the value $(D_1 - d_1)$ is unknown until $(D_1 + d_1)$ is found, an approximation must be used, which may be assumed as

$$D_1 - d_1 = (D_0 + d_0)\frac{k - 1}{k + 1} \qquad [8]$$

The value of the sum of the diameters $(D_1 + d_1)$ can now be found by solving [6]. In most cases the results thus obtained are sufficiently accurate for practical purposes. However, when the speed ratio k is large and the center distance very short, it is advisable to solve [6] a second time, substituting a closer approximation of $D_1 - d_1$, namely,

$$(D_1 + d_1)\frac{k - 1}{k + 1}$$

where $(D_1 + d_1)$ has the value as found in the first trial. This result is accurate enough for any condition met in practice.

The chart was evolved with the idea of eliminating as much as possible of the labor attached to calculating the correction number from Formulas [7] and [8]. For convenience in constructing the chart the expression for the correction number K can be written

$$K = \frac{\dfrac{(D + d)^2}{2\pi}}{\dfrac{1}{\left(\dfrac{k - 1}{k + 1}\right)^2} c}$$

The chart (Fig. 2) consists of four scales; the values on the scale representing the logarithm of the center distance c must be added to the value on the scale marked "Speed Ratio," which equals the logarithm of $1/[(k - 1)/(k + 1)]^2$, and the resulting logarithm should be subtracted from $\log (D + d)^2/2c$ on the scale marked "Sum Diameters." The remainder is the logarithm of the correction number and can be read on the fourth scale representing the correction number.

The procedure of calculating the correct diameters of any pair of steps for open-belt service can be best illustrated by an example. Given the diameters of a pair of even steps for ratio $k = 1$, each equal to 9 in.; center distance = 30 in.; speed of one shaft = 500 r.p.m.; speed of the other shaft = 100 r.p.m.

1 Add the diameters of the given even pair:

$$9 \text{ in.} + 9 \text{ in.} = 18 \text{ in.}$$

2 Express the speed ratio as follows:

$$k = \frac{\text{higher speed}}{\text{lower speed}} = \frac{500}{100} = 5$$

3 Set one point of a pair of dividers at 30 on the scale of Fig. 2 representing the center distance and the other point at 5 on the scale marked "Speed Ratio."

4 Keeping the above setting, place one point of the dividers at 18 on the scale marked "Sum Diameters;" the other point of the dividers will then indicate the first approximation of the correction number on the scale marked "Correction Number." In this example the first approximation equals 0.760.

5 Subtract this correction number from the sum of the diameters of the two even pulleys:

$$18 - 0.760 = 17.240$$

6 Keeping the same setting of the dividers as in (3), place one point at 17.240 on scale marked "Sum Diameters;" the other point will stop at 0.695, which is the second and closer approximation of the correction number.

7 Subtract this correction number (0.695) from the sum of the diameters of the even pair, then

$$S_K = 18 - 0.695 = 17.305$$

in which S_K is the corrected sum of diameters for the ratio $k = 5$.

8 The last step is to find the diameter of each pulley separately:

$$\text{Diameter of smaller pulley} = \frac{S_K}{k + 1}$$

$$\text{Diameter of larger pulley} = S_K - d$$

Then in the present example

$$d = \frac{17.305}{6} = 2.884 \text{ in.}$$

$$D = 17.305 - 2.884 = 14.421 \text{ in.}$$

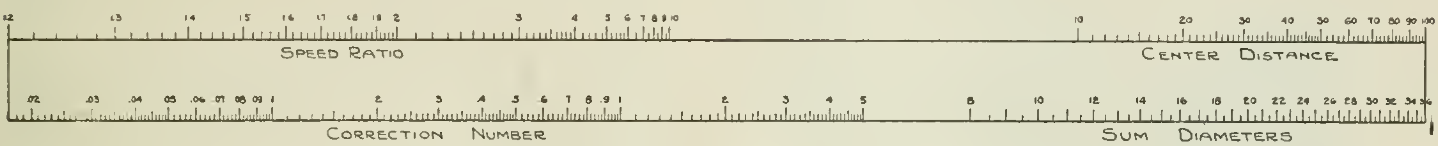

Fig. 2 Correction Chart for Use in Calculating Cone-Pulley Diameters

If the correction number is carefully read from the chart the final results will not vary on the average more than 0.005 in. from the most accurate mathematical calculations, and the whole procedure should not take over three minutes.

TABLE 1 CALCULATIONS OF THREE DIFFERENT CONE DRIVES

No.	c	k	$D_0 + d_0$	K from chart	S_K	D_1	d_1	L
1	40	1	32	.....	.....	.....	.....	130.266
	40	4	..	1.340	30.660	24.528	6.132	130.285
2	60	1	20	.....	.....	.....	.....	151.416
	60	3	..	0.256	19.744	14.808	4.936	151.417
3	30	1	18	.....	.....	.....	.....	88.274
	30	5	..	0.695	17.305	14.421	2.884	88.295

For the purpose of checking the accuracy of the chart, the diameters and the lengths of belts of three different cone drives have been computed, the results being given in Table 1.

David Turcott.

Beloit, Wis.

With Reference to the Discussion on High-Temperature and High-Pressure Steam Lines

To the Editor:

It has been called to my attention that as presented on page 294 of the May issue of Mechanical Engineering, the second paragraph of my closure to the discussion of my paper on High-Pressure and High-Temperature Steam Lines may be interpreted as an unfair criticism of Mr. Barrett, one of the discussors. Undoubtedly Mr. Barrett's discussion was prepared carefully and there was no desire on my part to pass on his engineering ability for which I have every respect. I desire to correct any different impression that may be derived from my closure.

B. N. Broido.

New York, N. Y.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities Papers and Proceedings of

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Immigration Policy Places New Responsibilities on the Engineer

H. V. Coes

FROM all sides we constantly hear of labor shortage. The deflation period in 1921 seemed to indicate a large surplus of labor. As soon, however, as business began to revive, as it did the past year, the temporary surplus was immediately absorbed, and now one important industrial executive estimates the labor shortage in the United States at the present time at 600,000. The people of the United States have made up their minds that they are going to control the character of the raw material that is to make up their citizenship and their neighbors, and the present policy is to restrict immigration from those countries whose people are not readily assimilated. The shortage threatens to become permanent.

A study of our principal industries such as textiles or steel shows a continuous shift in the various nationalities engaged therein over a long period of years. The probable reason for it is that the second or third generation of a given group of immigrants will not do the work their grandparents did—they have advanced to a higher scale of living and the unskilled worker is recruited from a new group of immigrants. This substitution of labor, both male and female, has run through the nations of Western Europe and, in the last decade or two, has largely focused on those of Eastern Europe. How much farther it can go in the white race it is hard to say. It has reached a point in certain places where there has been considerable agitation for coolie labor. I doubt very much whether the United States will ever admit labor of that class.

It has been the policy of the United States for over seventy years to depend upon immigration to furnish the necessary unskilled labor for our industries. Last year the number of immigrants admitted to this country was approximately 360,000; pending legislation would limit the eligibles to 170,000. The vital question, then, is, can the country expand and prosper with such a limited supply of new labor? A glance at the following statistics may be of interest.

Year	Number of Immigrants	
1820	8,400	
1830	23,000	
1840	80,000	Period of industrial expansion
1854	420,000	
1862	72,000	
1905	1,026,000	

In other words, when the United States was an agricultural country we did not need large immigration. As our industries developed, however, our immigration rose very rapidly. It fell to a low point on account of the Civil War, but throughout that period we received a total of about 620,000. In the past century the United States has received 35,000,000 immigrants. They have not all remained here, however. For instance, from 1909 to 1923, 5,500,000 departed, while our gain in immigration during that same period was 5,125,000.

The question is asked, What interest has the engineer in a restricted immigration policy? The answer is that the engineer, appreciating his important function in developing and sustaining civilization, must provide workers of metal and wood to fill the ranks that have normally been recruited from immigrants. Opportunity awaits the grasping. Capital will be required, but will undoubtedly be forthcoming to furnish backing for the design and manufacture of machines and devices that are commercially practical for lessening the hand work of the world. The increasing material needs of the inhabitant of a modern civilized country means that industry must increase. The new personnel for an increased industry will not come from restricted immigration even though quotas be made net, taking into account emigration and immigration. New and better machines under the guidance of modern management methods form an important part of the solution of the problem of labor shortage. Providing the machines and the management methods is largely an engineering responsibility. In other words, the engineer and management must devise ways and means to release common labor from some of its present assignments and graduate it into the ranks of semi-skilled and skilled labor, substituting therefor mechanical appliances to do the work previously done by common labor. This substitution need not, in fact should not, be confined to the activities now performed by common labor, but similar substitution must be made all along the industrial path if we are to maintain our industrial supremacy.

H. V. Coes.[1]

Coast to Coast by Air

THE flight of Lieutenants John A. Macready and Oakley G. Kelly from Long Island to San Diego is primarily of interest as showing the progressive spirit governing the Army Air Service.

It is certainly no accident that at the time of this writing several world records are held by the Department, among others such important ones as the speed record, the endurance record, and now the non-stop distance flight. (The fact that for technical reasons this particular record cannot be homologated by the International Aeronautical Association, does not, of course, in any way affect its authenticity or value.) The coast-to-coast flight was a severe test not only of the plane and engine, but also of the training and personal ability of the men. Moreover it is not an isolated performance, a stunt. The same men have flown for other long distances, though not as great, of course, as that covered in the present flight. Other flights such as the one from Long Island to Alaska and particularly the recent flight to Porto Rico have shown that the Army Air Service is capable of what would have appeared to be only a few years ago unbelievable performances.

The machine used was a T-2 monoplane designed by Anthony G. H. Fokker and built by the Netherlands Aircraft Corporation to take the Liberty motor. The structural weight empty is 5100 lb. and the useful load for commercial operation is 3500 lb. The total wing area is 940 sq. ft. The maximum speed fully loaded is 105 miles per hour, and the ceiling approximately 11,000 ft.

In order to adapt the machine for the coast-to-coast flight certain changes were made. By the use of an extra tank in the cabin and an extra gravity tank in the wing, the total gasoline capacity was increased to some 735 gal. and the oil capacity to 30 gal. The total

[1] Chairman, Materials Handling Division, A.S.M.E.

weight fully loaded was thus increased to over 10,000 lb. An oil radiator was provided. Anti-leak compound with an appropriate pressure pump was carried for use in the radiator or water jackets in case of leak. A special tank was provided to catch overflow from the radiator or its expansion tank, so that the loss of water on a long trip was minimized. Spare batteries were taken along, as well as a spare glass tube for the gasoline level gage among other items. A second set of flying and engine controls were installed in the cabin, with a communicating door between the pilot and the cabin so as to facilitate interchange between the two men. A liding door was provided near the pilot in order to enable him to thrust his body right outside the plane.

The power plant was a Liberty engine, and it is stated that, with the exception of a short period at the beginning of the trip, it operated at about 90 per cent of its full power throughout the flight.

The present flight, as well as the flight from England to Australia by the Smith brothers in their Vimy biplane, has shown that highly experienced fliers can find their way even under adverse conditions by compass and dead reckoning. It has also shown, however, that it takes a highly experienced flier to do so, and that lack of ground markings is a serious obstacle to long-distance flight.

It may be a long time before flying from New York to San Francisco will become an every-day occurrence and a means of saving time for the ordinary busy man. Lady Carnarvon's attempt to reach her dying husband by air from England to Egypt, it may be said, failed mainly because of the extreme discomfort of long flight to those not accustomed to that mode of travel.

From a military point of view, however, the importance of the achievement of Macready and Kelly is very clear, and it is also of unquestioned significance as showing that while the number of planes available to the War Department is pitifully small for such a great country as ours, the men in the Department are capable of performing wonders even with what equipment they have.

Store Winter Coal Now!

ALL INDUSTRIES and individuals are asked to store a winter's supply of fuel during the summer months. The Coal Commission has pointed out that the storage of coal in this manner will even the demand for coal throughout the year, thereby rendering its production more economical and equalizing the demand for transportation. Secretary Hoover, in a letter to the Society, points out that the producing capacity and consuming demands of the country have advanced beyond our transportation facilities, and stresses the importance of both consuming and producing industries coöperating with the railroad managements to secure the most efficient operation of their lines. The transportation peak of the country occurs during October. It is extremely important, therefore, that coal be purchased and stored within the next three months so that the burden of moving this fuel will not be added to the difficult transportation period of the fall.

The importance of storing coal applies not only to the railroads, the public utilities, and the industries, but also to domestic users. The Storrs Plan of domestic coal storage was outlined in the May issue of Mechanical Engineering.

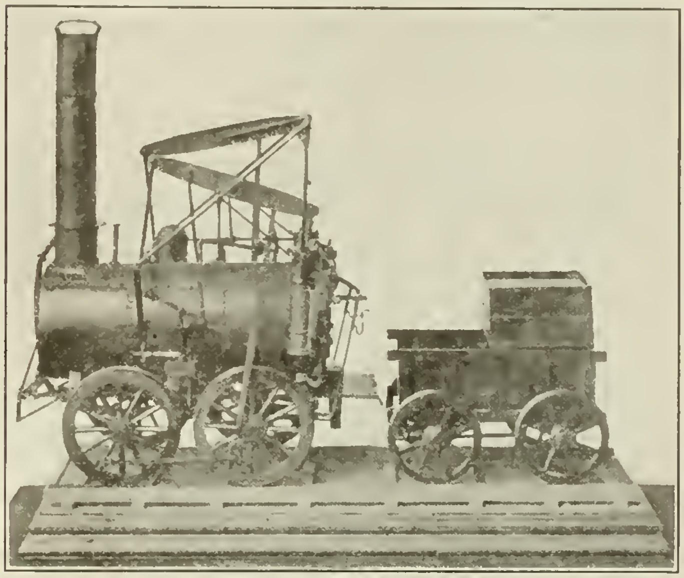
The American Engineering Council has appointed a committee to make a coal-storage survey and issue an authoritative statement covering the engineering, chemical, and economic factors involved in the storage of coal, and how they may be employed to relieve the present complex coal situation. It is hoped that this committee will report early in November, 1923.

The problem of coal storage is far-reaching and fundamental. It places a responsibility on each member of the Society to discuss the subject in his business and social contacts and arouse general public attention. The organized groups of the Society are mobilizing for duty. The Fuels Division is assisting the committee of the American Engineering Council, and in addition will hold a session at the A.S.M.E. Annual Meeting in December with papers on the storage of fuel. The Materials Handling Division is coöperating in the arrangements for this session. Each Local Section will be called upon by the American Engineering Council committee to assist in the survey.

Store winter coal now!

One Hundred Years of Transportation

THE centennial celebration of the Delaware and Hudson Company has served to recall the efforts of pioneers in creating a market for the "stone coal," as anthracite was then called, which was discovered near Carbondale, Pa., in 1799. There was doubt as to the ability of "stone coal" to burn on a grate. However, the war of 1812 cut off the normal supply of charcoal and the use of anthracite as a substitute was pushed. About this time William Wurts obtained a large acreage of coal lands near Carbondale and, with his brother Maurice, opened mines and attempted to market the product in Philadelphia. They were compelled to abandon this project to their competitors who were more advantageously located, and turned to New York for the outlet. So the Delaware and Hudson Company was organized to construct a canal connecting the waters of the Delaware and Hudson Rivers. A portion of



The "Stourbridge Lion," the First Steam Locomotive Run on Rails in America

the route from mine to market was over a range of mountains and a gravity railroad was built using inclined planes and stationary hoisting engines.

In 1829 four locomotives were imported from England for use on the gravity railroad. The *America*, built by George Stephenson, arrived on January 15, 1829, and the other three, built by Foster Rostrick, came in May. On August 8 one of the three, the *Stourbridge Lion*, was operated on a section of the track. The test convinced the engineers that the track would not stand the weight of the *Lion* or the side thrust of the wheels on curves. Rebuilding the road to withstand the stresses was considered but for various reasons was found to be impracticable, and the use of locomotives abandoned. The *Stourbridge Lion* was the first locomotive placed on any track outside of England and the first that ever turned a wheel on the Western Hemisphere. It was imported solely to transport and market anthracite.

In a country depending so completely on transportation as does the United States, the centennial of a pioneer transportation company is of great interest. Certainly we can have no accurate conception today of the courage of the pioneers who overcame the prejudices against anthracite and who conquered the physical difficulties of bringing the coal to market.

Transportation conditions a century ago were in at least one respect similar to those of the present day. Locomotives had been known for twenty-five years before the importation of the four engines by the Delaware and Hudson Company. The locomotive did not come into general use, however, until the demands for its services could be met commercially. Today the airplane, largely a war development, is waiting for commercial needs to require its unique transportation ability and to compel the expenditure of money for the research and development that will perfect it for commercial use.

Engineering in India

ENGINEERING projects of great magnitude are under way and under consideration in India, according to a report recently submitted to the Department of Commerce by Trade Commissioner Batchelder. It is estimated that nearly a million dollars is needed to carry out all the plans, among which are the following:

The Madras Presidency proposes to expend about $45,000,000 within the next five years, for irrigation, roads, and other public works. Bombay plans to spend $61,000,000 on irrigation alone, besides continuing the port-development works and the new schoolhouses required to carry out the terms of the new compulsory education act. The United Provinces need $30,000,000 within the same period for irrigation, forests, and other public works, while the Punjab has extensive plans for irrigation and hydro-electric plants requiring $140,000,000 before 1940.

Bengal has decided to build a $10,000,000 bridge across the Hoogly in Calcutta, and there will be further expenditures on the improvements of the port and for ameliorating the housing and congested traffic problems. The total desired for all these government and municipal public works cannot be less than $300,000,000. Besides, it is intended to spend about $500,000,000 in the next five years for new construction, repairs, and additional rolling stock on the government railways.

Some interesting communications concerning engineering in India have come during recent months from J. D. Rogers, representative of The Baldwin Locomotive Works at Calcutta. Mr. Rogers has spent some time in Africa—nearly three years in South Africa and later traveling in Portuguese East Africa and neighboring sections. His message to every American who has gone or expects to go into the foreign field of engineering is to remember that he represents not only some particular interest but the whole American engineering profession. Extracts from Mr. Rogers' letters follow:

India offers great opportunity for capital to be employed in development such as manufacturing, extension of irrigation, and making the great river system navigable. With proper expenditures of money the terror of the monsoons can be eliminated. There will be no suffering from either drought or flood. The Bengal government is to spend $2,000,000 on a canal at Calcutta. The engineer in charge tells me that all of his estimates are based on using American equipment, as we have solved the question of eliminating labor.

I have made a complete circuit of India; this means covering an area equivalent to about two-thirds of that of the United States. Travel here is very comfortable as the railway equipment is well adapted to the conditions. There are about 15,000 miles of broad-gage, 3 ft. 6-in. lines, and the same of meter-gage; this is supplemented by some 5000 miles of narrow-gage, 2 ft. 6 in. and 2 ft. Railways are not only vital in the economic development of India but are the means of distributing the food to the 350,000,000 people. Great famine funds which were provided by taxation are now being spent in further development, not only of railways but vast irrigation projects. At present the Punjab project is under way; it far exceeds anything ever undertaken in America and will make a barren desert as productive of cotton as our best southern states.

It is very gratifying to see the interest the railway men of India take in our American engineering. Just now there is a strong tendency toward our locomotive designs. I am here now in Delhi to discuss the standardization of locomotives with the Railway Board, the functions of which combine those of our Interstate Commerce Commission and the Railway Administration. They have to approve every policy of the Indian Railways, both engineering and financial. They are a very high-grade body of men, representative of the very best in India.

Conference of Women Engineers Held in England

SOME forty delegates convened by the Women's Engineering Society met at Birmingham University on April 12 and 13 in the first conference of women engineers ever held. The presidential address of Lady Parsons was followed by an outline of the history of mechanical engineering by Prof. F. W. Burstall, Dean of the Faculty of Science, Birmingham University. Professor Burstall discussed the social and ethical effects of scientific progress, stating that the human element must be the predominant issue in all matters of engineering development. He later conducted the delegates in an inspection of the engineering department of the University.

At an evening session on April 12 Miss M. Partridge, of M. Partridge & Co., domestic engineers, Exeter, read a paper based on her experience in electrical contracting work in country districts.

On April 13 a paper by Mrs. L. M. Gilbreth, whom illness prevented from being present as representative of The American Society of Mechanical Engineers, was read by Miss C. Haslett, secretary of the Women's Engineering Society. Her article was a brief exposition of the growth in the breadth of interest of the engineer, in his work, and in his field of influence.

Miss Entwisle, of the Metropolitan-Vickers Electrical Co., Ltd., Manchester, presented a paper entitled Some Considerations of Electrical Design. Mme. Laurent, who, with her husband, attended the conference as directors of the Ecole Technique Feminin de Paris, and as representatives of the French Government, gave a short lecture, illustrated with lantern slides, on the gradual development of women engineers in France. The convention closed with a trip to Stratford on Avon on April 14.

Dr. George K. Burgess Becomes Director of the Bureau of Standards

THE DIRECTORSHIP of the U. S. Bureau of Standards has recently been placed in the hands of Dr. George K. Burgess, who has been connected with the Bureau since 1903 and since 1913 has been chief of the Division of Metallurgy. His long association with the Bureau, and his intensive research work, particularly in iron and steel, make him well qualified for his new position.

Dr. Burgess was born in Newton, Mass., in 1874, received the degree of B.S. from Massachusetts Institute of Technology in 1896, held a fellowship there from 1898 to 1900, and obtained his Sc.D. from the University of Paris in 1901. He was instructor at the University of Michigan for one year, and at the University of California for two years, previous to entering the Bureau.

As a member of the National Research Council Dr. Burgess has been active in its committee work. He represents the Department of Commerce on the American Engineering Standards Committee and is this year's president of the American Society for Testing Materials.

Sir J. J. Thomson Visits America

SIR JOSEPH JOHN THOMSON, F.R.S., who has been a visitor in this country during recent weeks, was awarded the Franklin Medal at a special meeting of the American Philosophical Society in Philadelphia on April 10. He likewise received the John Scott medal and award of $1000. The subject of his address on this occasion was the possibility of a new form of water molecule.

Sir Joseph, for many years Cavendish Professor at Cambridge, and now Master of Trinity College, came here under the auspices of The Franklin Institute to give a series of lectures before that institution on The Electron in Chemistry. These lectures, with due regard to progress of science, may be said to be a continuation of those delivered by Lord Kelvin before the same body.

Sir Joseph was the speaker at the dedication of the Sterling Laboratory at New Haven on April 4, and on April 6 and 7 visited the Research Laboratory and the Schenectady Works of the General Electric Company, giving an informal talk to the laboratory staff and engineers and evidencing much interest in the work they are carrying on.

Mr. Dickinson of South Kensington Museum Visits the United States

H. W. DICKINSON, Assistant to the Director of the Science Museum at South Kensington, London, and Honorary Secretary and Treasurer of the Newcomen Society, visited New York, Washington, Philadelphia, Boston and Dayton during April and May.

Mr. Dickinson is keenly interested in the history of engineering and technology, developing interest in which is one of the important objects of the Newcomen Society. On his trip Mr. Dickinson was the guest of several groups of engineers who have displayed an appreciation of the value and importance of engineering history.

Mr. Dickinson was a speaker at the dinner celebrating the Centennial of the Delaware and Hudson Company on April 23. His topic was the early development of the steam engine.

The Engineer in Public Affairs

GANO DUNN was the presiding officer at the meeting, held May 8 in the Engineering Societies Building, devoted to the "Engineer in Public Affairs." The gathering was under the auspices of the New York Sections of the American Society of Civil Engineers, the American Institute of Mining and Metallurgical Engineers, The American Society of Mechanical Engineers, and the American Institute of Electrical Engineers. In addition there were present representatives of the Society of Municipal Engineers, Society of Automotive Engineers, American Society of Heating and Ventilating Engineers, the American Society of Safety Engineers, the Taylor Society, the Society of Illuminating Engineers, and the New York Society of Architects. The speakers of the evening were Admiral John Keeler Robison, Engineer in Chief of the United States Navy, and Frank Jewett, president of the American Institute of Electrical Engineers and Chairman of the Engineering Division of the National Research Council.

Mr. Dunn opened the meeting in the following well chosen words:

> Engineers have inscribed in this Temple of Engineering, in the great library that crowns our building and the efforts of many years, the legend, "Engineering is the art of organizing men and controlling and directing the forces and materials of nature for the benefit of the human race." Now, when we come to discuss the Engineer in Public Affairs, that discussion necessarily turns our attention rather more toward the side of engineering that has received more attention in late years than ever before, the side of the engineer's generalship, the side of the engineer's organizing capacity, the side of the engineer's human contacts. There has never been a time when the demand for the education of engineers in the humanities as well as in the sciences and the technologies has been as great as it is today. There never has been a time when the demand for the education of engineers in English, in literature, in the fine arts, has been as great as it is today. The reason is an appreciation, not only on the part of engineers themselves, but on the part of those with whom they work, that an engineer must be an all-around man before he can reach the heights of engineering. The groping and straining towards a larger part in national affairs that have been concomitant with the development of the national and other engineering societies in the last twenty years has been due to the feeling within engineers themselves that their places as citizens are more and more responsible as every day goes on.
>
> For my own part I think there has been a waning of opinion in engineering circles that has overemphasized the desirability, if not the appropriateness, of a certain extreme degree of participation of engineers in public affairs. On the other hand, the increasingly essential relation of engineering works and structures, engineering operations, engineering conceptions, and even engineering terms and habits in the daily life of the people of the United States, has been so marked that engineering of itself has been taking a greater and greater part in public affairs, and if the engineer cannot keep pace with his subject, then he certainly is unworthy of the name.

In introducing Admiral Robison, Mr. Dunn paid a tribute to the engineering service of the United States Navy and read the following engineering creed sent to Admiral Robison when he was appointed Engineer in Chief of the Navy and which served to inspire him in no small degree:

> The idea of devotion to duty as a measure of worth, of worth as a measure of happiness, and of service as the proper aim of each of us, I believe to be true. Particularly do I believe that lasting happiness is found only through the medium of unselfish service. The thought of self in service, no matter how big the service, runs counter to nature's laws of compensation. Self-glorification and contentment of spirit are not found on the same trail.

Admiral Robison pointed out that the opportunity facing engineers in public service must be grasped that the common weal of the whole mass of humanity may be accomplished. Originally all engineers in public service were civil engineers. The word "civil" is a derivation meaning a man who is a "builder for the state." Today there are many specialized branches of engineering but the basic reason for the existence of any kind of engineer is that he is a builder for the state. Admiral Robison then told of the remarkable work being carried on in the engineering department of the Navy. He emphasized the fact that, if the shores of this country are to be kept unpolluted by war, the ships or our Navy must be able to take any desired position and take it first. The ships must move far enough and stay there long enough. The ability to do this is an engineering problem. The task of moving a fleet between two points involves reliable machinery and plenty of fuel. Increasing the fuel radius of the individual vessels and installing machinery of greater reliability and economy was emphasized by the Admiral as important steps in increasing the mobility of the ships. The preparation of detailed instructions in the use of fuel and the enforcement of these instructions proved to be a considerable factor in reducing the expenditures for fuel by 32.03 per cent per knot under way and 49.7 per cent per day in port.

Admiral Robison also told of the great work the United States Navy had accomplished as a humanitarian agency. In closing he emphasized the tremendous importance of the spirit of service which is not peculiarly naval. He said they are but representatives of the noblest profession in the world, builders of things and of character.

In introducing Mr. Jewett, Mr. Dunn called attention to the fact that the meeting of the evening had been organized by the Federated American Engineering Societies and that representatives of all branches of the profession were present. Mr. Dunn expressed his views about the F.A.E.S. in the following words:

> The Federation is, up to date, the result of the outgrowth and the embodiment of those things in engineers which they feel can be done better united than separate.
>
> The Federation is going through a period which confronts bodies in similar circumstances in other realms. The details of its operations and accomplishments must be ultimately that nice balance between strong opposing forces upon which the health of an organization always depends. The history of our own country illustrates that: at the beginning it was almost impossible to form the federation which was called the United States of America. Even our own New York did not sign the Declaration of Independence until three or four months after the Fourth of July.
>
> Now, while in the ranks of engineers there is not today that agreement which many of us would like to see, I think if we all stand off a distance and look, we will get a perspective that will be of great value. I hold these principles to be self-evident, that engineers cannot continue to go on as entirely separate and distinct organizations, that there is something in the human side of all the engineering branches that needs contact with other branches, and that there is an as yet undeveloped force and power among engineers as a profession that, if properly united, polarized and made to pull all one way, can speak for engineers, can represent them, and can make them a force in the community that they have not as yet been made.
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> Now, these things being so, it is not a question of whether or not engineers shall federate; they are already federated; this meeting tonight illustrates it. It is only a question of the details that that federation shall take, and, therefore, I think we can pay no greater tribute to the engineers as a profession than by adopting the confident belief that some kind of federation is a necessity, and that some kind of useful, successful, and effective federation is absolutely bound to come.

Mr. Jewett in his address further emphasized the belief that some sort of joint organization of engineers is necessary and that an effective federation should be developed in the future.

Los Angeles Regional Meeting

THE highly successful Los Angeles Regional Meeting on April 16 through 18, 1923, was reported in brief in the May 7 issue of the A.S.M.E. News. We received the corrected stenographic report of the excellent dinner addresses and the discussion at the technical session too late to give the proper space in this issue. They will be used in later issues of Mechanical Engineering.

Engineering Index and Library Combine to Serve Engineer

REFERENCE was made in the preceding issue of Mechanical Engineering to statements by Prof. W. Trinks in regard to technical literature. The paucity and inadequacy of engineering libraries in the country to which he calls attention need not be a serious problem for engineers in country districts if the following points are noted.

Back of The Engineering Index for 1922, which has just been issued, is the Engineering Societies Library of New York, from which may be obtained, at a nominal cost, photostatic reproductions of the text of any article indexed.

Some thirty per cent of the periodicals indexed in this volume are in foreign languages. The Library will furnish translations of articles from any of these. The list of bibliographies in this volume is more extended than in preceding years. Mr. Raymond Brown of the Library Staff assisted in the compilation of this list.

The Engineering Index is not an exhaustive guide to the engineering literature of the world but it does index what are considered the leading articles on the newest developments of the year. The services of the Engineering Societies Library are prompt and efficient. The combination should be of unequalled value to engineers, engineering students, and research workers everywhere.

Engineering and Industrial Standardization

Standardization of Mathematical and Graphical Symbols and Abbreviations

A RECENT conference held in New York under the auspices of the American Engineering Standards Committee revealed sentiment among engineers, scientists, government officials, business-paper editors and industrial executives emphatically in favor of the unification of technical and scientific abbreviations and symbols.

It was agreed on all sides that the standardization of abbreviations and symbols would result in inestimable mental economies. The present situation with respect to the use of abbreviations and symbols in engineering, scientific, and other technical fields is comparable to a language which has degenerated into a multiplicity of dialects, each of which has to be translated for the users of the others. Abbreviations and symbols constitute an ever-growing and important part of the language of engineers, scientists, industrial editors, and other technical men. The use of one symbol or abbreviation for several different terms and the use of several different symbols or abbreviations for one meaning are, however, at present causing a great deal of confusion, misunderstanding, and often serious errors.

The conference was called upon requests from the American Institute of Electrical Engineers, The American Society of Mechanical Engineers, and the Association of Edison Illuminating Companies to consider abbreviations and mathematical symbols, but after some discussion of the subject it was thought desirable to include as a part of the project the graphical symbols which are used in engineering drawings, diagrams, and the like, for representing instruments and apparatus and their components.

It was agreed that the coöperation of foreign standardizing bodies should be sought in the development of the work. The importance of international uniformity in symbols is great on account of the international character of much engineering and scientific work, and the importance of reference books and periodicals in foreign languages.

The work will go forward under a Sectional Committee organization developed in accordance with the rules and procedure of the American Engineering Standards Committee.

Recent Progress in Standardization of Particular Interest to Mechanical Engineers

Walkway Surfaces. The American Engineering Standards Committee has invited the American Institute of Architects and the American Society of Safety Engineers to act as joint sponsors for the proposed safety code on walkway surfaces.

Petroleum Products and Lubricants. Standard methods of testing petroleum products and lubricants will be developed by a sectional committee organized under the sponsorship of the American Society for Testing Materials as a result of recent action by the A.E.S.C.

Flash Point of Volatile Flammable Liquids. The A.E.S.C. has approved as "Tentative American Standard" the standard method of test for flash point of volatile flammable liquids submitted by the American Society for Testing Materials. The A.S.T.M. has been appointed sponsor for this standard, and in this capacity will publish the standard and direct any revision of it that may later be necessary.

Radio Apparatus. Sponsorship for radio standardization has been assigned by the American Engineering Standards Committee to the Institute of Radio Engineers and the American Institute of Electrical Engineers, jointly. This action was taken in accordance with the recommendations of the large representative conference called by the Bureau of Standards.

Safety Code for Forging Industry. The formulation of a national safety code for the forging industry will be undertaken immediately as a result of the decision of a conference of the principal organizations interested in the subject recently held in New York on the call of the A.E.S.C., under whose procedure the code will be developed.

The conference by resolution requested that the code include the hazards of drop forging and other hammer forging, as well as all hazards peculiar to the forging industry and associated with the machines used in the industry whether or not they occur at the point of operation. The same resolution suggested that the code do *not* include the hazards of cold extrusion of non-ferrous metals, or hydraulic presses, except as the Sectional Committee may find it desirable to include small types of the latter and that the inclusion of hot pressing, bulldozing, and other forging operations, such as those of bolt-heading and rivet-making machines, be left to the discretion of the Sectional Committee.

Colors for Traffic Signals. Forty-two men, representing the manufacturers and users of traffic signals, federal and state governmental departments, associations interested in the prevention of traffic accidents, and representatives of the general public, are now at work on the drafting of a national code on the proper colors for traffic signals, which it is expected will not only cut down the annual loss of life through traffic accidents, but will eliminate any of the existing irritations to motorists and to the operators of steam and electric railways.

This work is being carried on under the auspices of the A.E.S.C. whose approval of a code or standard insures its ultimate acceptance and observance throughout the country. The Sectional Committee drafting this code is made up of seven representatives of the manufacturers of traffic signals, nine representatives of the purchasers of such equipment, three representatives of the users of traffic signals, twelve representatives of governmental bodies, five technical specialists, and six insurance representatives. The American Engineering Standards Committee is composed of seven departments of the U. S. Government, the principal technical, industrial, and engineering societies, and individual business concerns interested in standardization.

Six Electric-Railway Rail Standards. The A.E.S.C. has approved as "American Standard" six of thirteen specifications covering the design of steel rails and their accessories, which have been submitted by the American Electric Railway Association, one of the pioneers in industrial and engineering standardization. Considerable progress has been made in the consideration of the remaining specifications.

The specifications which have been approved cover the design of the following: Nine-Inch Girder Grooved Rail; Seven-Inch Girder Grooved Rail; Nine-Inch Girder Guard Rail; Seven-Inch Girder Guard Rail; Joint Plates for Seven-Inch Girder Grooved and Girder Guard Rails; and Joint Plates for Nine-Inch Girder Grooved and Girder Guard Rails. Some of these specifications were adopted as standard by the A.E.R.A. as far back as 1907. The extent to which they have come into general use is indicated by the fact that one of the principal manufacturers of steel rails reports that approximately 79 per cent of his total tonnage of girder rails shipped to electric railways during 1922 was A.E.R.A. standard. This same company reports that during the past seven years 62 per cent of its total tonnage of electric-railway girder rails was A.E.R.A. standard.

Code on School Lighting. The lighting, building, education, health, and social agencies of the country have joined hands in an effort to develop a nationally accepted code for school lighting which will correct the conditions partially responsible for the defective vision of 10 to 20 per cent of the school children. The A.E.S.C. has appointed the American Institute of Architects and the Illuminating Engineering Society joint sponsors for a Code on School Lighting. The sponsors will organize a representative sectional committee to formulate the code and will provide for the publication of the code after it has been approved by the A.E.S.C.

Standardization in Denmark. The A.S.M.E.'s correspondent in Berlin reports as follows: "According to the Danish newspaper *Ingeniören* Nr. 2 of January 13, 1923, the Standardization Committee of that country held a meeting on December 12, 1922,

at which the question of coöperation with other national standardization committees was discussed. During this discussion it was pointed out that if it is a question of coöperating with one country, that country would most likely be Germany, as working with England is impossible on account of the inch system of measures in use there. A complete adherence to German standards may, however, easily lead to dependency; the more so as there is hardly any Danish export of industrial products to Germany."

Although it may readily be admitted that the German standards will be worked out perfectly, it is on the other hand almost certain that small Denmark will have no influence on such standardization. It was finally agreed, therefore, to strive for the creation of Inter-scandinavian Standards by Finland, Norway, Sweden, and Denmark.

Ice-Cooled Domestic Refrigerators. The American Institute of Architects has requested the A.E.S.C. to arrange for a national conference of all interests involved to consider the desirability and feasibility of establishing standards for ice-cooled domestic refrigerators both as to size and cooling per pound of ice melted. The American Institute of Architects is prompted to make this request by the belief that it is both desirable and feasible to establish a standard rating for domestic refrigerators, based upon thermal conductivity. There are, of course, many other features of design and construction affecting refrigerator efficiency which should be considered. There is today no criterion for ice-box efficiency by which either the public or the architectural profession may judge of values in terms of ice economy and food preservation. There is a wide variation in the chilling effect of the melting of a pound of ice in the various types and makes of domestic refrigerators now on the market. Some of them are practically worthless. Not only are they wasteful of ice, but they also constitute a menace to health in that they do not preserve the food placed in them.

Sizes for U. S. Flags. Most every one assumes when they buy a flag that it is an exact replica of "Old Glory." True, it has 13 stripes and 48 stars, but the size may be one of several hundred that do not conform to Government standards. On October 23, 1922, flag manufacturers met in conference with representatives of the Army and Navy, and others interested, to determine upon a method for establishing flag sizes which would be comparatively few in number and, moreover, would conform to the standards acceptable to our Government. An executive order by President Wilson in 1916 set up 12 sizes as standards for United States flags, and it is upon the basis of this, together with a survey by the manufacturers, that a subsequent conference is contemplated for the final adoption of national standards for flag sizes.

The Late Dr. Schuyler Skaats Wheeler

A LEADING inventor and engineer in the electrical field, Dr. Schuyler Skaats Wheeler, died suddenly of angina pectoris on April 20, 1923, in the sixty-third year of his age. Dr. Wheeler was born in New York and was graduated from Columbia University in 1881. After a few minor connections he became a member of the staff of Thomas A. Edison, and for three years was engaged in installation work. From 1886 to 1888 he was connected with the C. & C. Motor Co., which he helped to organize.

In 1888, the Crocker-Wheeler Company, of New York and Ampere, N. J., was formed with Dr. Wheeler as president, a position which he occupied up to the time of his death. This company was the first in the world to manufacture small electric motors, and during the past thirty-five years has installed more than 1000 electric drives designed by Dr. Wheeler.

Dr. Wheeler was an organizer and founder of the United Engineering Societies, and was a member of the national, civil, electrical, and mechanical engineering societies. He was for a time president of the American Institute of Electrical Engineers, to which he gave the Latimer-Clark library, said to be the largest collection of rare electrical books in existence. He became a member of The American Society of Mechanical Engineers in 1899.

Water-Power Resources of Canada

WATER power is one of Canada's most basic and valued natural resources. The capital invested in this development, well over half a billion dollars, makes it also one of her greatest single industries. The Water Power Branch of the Canadian Department of the Interior has for the past three years been collecting and analyzing data, and in a recent report presented some of its results.

The known available water power in Canada is 18,255,000 hp. for conditions of ordinary minimum flow and 32,076,000 hp. under a flow of estimated maximum development, that is, dependable for at least six months of the year. These estimates have been made on the basis of 24-hr. power at 80 per cent efficiency. The ordinary minimum flow is based on the averages of the minimum flow for the lowest two consecutive seven-day periods in each year over the period for which records are available. The estimated flow for maximum development is based upon the continuous power indicated by the flow of the stream for six months in the year.

The Interior Department believes that these are conservative estimates since an analysis of existing water-power plants scattered from coast to coast, concerning which complete data are available as to turbine installation as well as satisfactory information regarding stream flow, gives an average machine installation 30 per cent greater than the six-months'-flow maximum power. Applying this to figures quoted above indicates that the present recorded waterpower resources of Canada will permit a turbine ininstallation of 41,700,000 hp.

The total capacity of the water wheels and turbines installed is 2,973,759 hp. or 338 hp. per thousand population. Canada's position is second only to that of Norway in the per capita utilization of water power.

In the central-station industry in which there is an installed turbine capacity of 2,204,486 hp., 1,556,956 hp. is installed in privately owned stations and 647,530 hp. in publicly owned stations.

Pulp and paper manufacturing is a typical and preëminent Canadian industry with a future of almost unlimited prosperity ahead of it, the result of two natural advantages of almost equal moment, namely, an abundant supply of growing pulpwood and cheap accessible motive power in large quantities. The importance of cheap power lies in the fact that it takes practically 100 hp. to produce one ton of paper per day. It is not surprising, therefore, that the motive power used in this industry is almost altogether restricted to hydraulic energy and that Canada's premier advantage and position in the pulp and paper field rest on adequate and abundant water power well distributed among extensive forest reserves.

Water power is operating 113 pulp and paper mills in Canada, 664,805 hp. being employed. Of this total, 482,228 hp. is actually installed in connection with the mills and 160,577 hp. is purchased from hydroelectric central stations.

The innovation of the electric drive is having a marked and favorable influence on pulp and paper manufacturing processes. It makes possible the centralized operation of fewer and larger mills receiving power from several power sites, together with the further advantages of uniform speed and better control in grinding, thus lessening costs of operation, construction, and shipping. Of the 484,228 hp. actually installed in pulp and paper mills 183,311 hp. is used in the electric drive, besides which there is 160,577 hp. of hydroelectric energy purchased from central stations, thus bringing the total horsepower that is employed in the electric drive up to 343,888.

The water power now developed in Canada represents an investment of over $620,000,000. In 1940, should the rate of growth in installation during the past fifteen years be continued, this investment will have grown to over $1,100,000,000. The present development represents an annual equivalent of 26,700,000 tons of coal, which, valued at $10 per ton, represents $267,000,000. In the year 1940 these annual figures will, with the foregoing assumption, have become 50,000,000 tons and $500,000,000, respectively.

Meetings of Other Societies

American Society of Civil Engineers

The river and harbor problems of the lower Mississippi was the general subject under discussion at the spring meeting of the American Society of Civil Engineers held at New Orleans, April 18–20, 1923. A number of the eleven papers presented at the two technical sessions dealt with navigation control and operation, and the others with flood control. Maj. L. H. Beach, chief U. S. Corps of Engineers, described the work of the Engineers' Corps on the Lower Mississippi, A. L. Dabney, consulting hydraulic engineer, the success of the levees during the flood of 1922, and L. H. Parmelee, consulting engineer, Helena, Ark., the high-water fight at Old Town, Ark., in 1922.

The economic location of jetties was discussed by Henry C. Ripley, consulting engineer, Detroit, Mich., and river control by John Klorer, city engineer of New Orleans. Transportation on the Mississippi River was the subject considered by two speakers, M. J. Sanders, manager of the International Mercantile Marine and the Frederick Leyland Company, Ltd., New Orleans, La., and the Hon. Joseph E. Ransdell, U. S. Senator from Louisiana. The former took up the question of the revival of commercial transportation, and the latter spoke on the economics of transportation.

The port problem was also the subject of two papers, presented by John F. Coleman and Samuel M. Young, both of whom are associated with the Board of Port Commissioners, New Orleans. Elliott J. Dent, Lt-Col., U. S. Corps of Engineers, presented a paper entitled The Mouths of the Mississippi River.

John R. Freeman, a past-president of the society and now consulting hydraulic engineer, Providence, R. I., pointed out the necessity of an experimental hydraulic laboratory for the solution of river problems. Mr. Freeman discussed the present state of knowledge of river hydraulics, described the few experimental laboratories of the kind sought, and the suggested design for the one proposed in Senator Ransdell's bill presented at the last session of Congress.

An all-day excursion by steamer to points of interest in New Orleans Harbor, Inner Harbor Canal, and Lake Pontchartrain gave the members an opportunity to study conditions for themselves. The trip covered the entire harbor frontage of the Mississippi River on both sides.

Previous to the meeting the Board of Direction held a two-day session. Among the items of business transacted was the authorization of a committee of five to confer with other national societies looking toward coöperation in matters of interest in public affairs; the approval of the recommendations for Government reorganization, particularly of those tending to divorce civilian engineering activities of the Government from engineering duties which are under military control; and the acceptance of two grants from Engineering Foundation, one of $1000 for the investigation of concrete and reinforced-concrete arches, and the other of $4000 for the investigation of steel columns.

The next meeting, on the subject of highways, will be held in Richmond, Va., sometime in October.

Society of Industrial Engineers

The major subject of the tenth annual convention of the Society of Industrial Engineers, held in Cincinnati, April 18 to 20, 1923, was the effective management of the moderate-sized plant. Prof. Joseph W. Roe, president of the society, who spoke on Three Phases of Management: Financial, Sales, and Production, at the opening session, stated that although the large plant had a great advantage over the small one in the field of purchases and sales, in actual production the small plant could frequently compete with the large one on even or on better terms.

Speaking at a meeting of the educational group of the society on Economics and the Smaller Plants, Ernest F. Du Brul, general manager of the Machine Tool Builders' Association, presented figures from the Census of Manufacturers, 1919, which he believes verify statistically the economic principle that the division of labor is an economic benefit, not only in increasing product per man but also in increasing profit until a point of maximum efficiency is reached. Mr. Du Brul therefore advocates the concentration of industry in larger establishments.

Meetings of the production and personnel groups were also held, Chester B. Lord, industrial engineer, National Automatic Tool Co., Richmond, Ind., addressing the former on Production Control Systems for the Special Order Shop, and J. J. Davis, Paine Lumber Co., Oshkosh, Wis, the latter group.

Chief among the general sessions was that given over to a discussion of workers' participation in management. The workers' side was presented by John P. Frey, editor of the *International Molders' Journal;* the employers' side by Charles R. Hook, general manager, American Rolling Mill Co., Middletown, Ohio (read in his absence by M. E. Danford, of the same company); and the engineers' side by John Calder, consulting engineer, Lexington, Mass. Daniel Bloomfield, Boston, editor of *Industrial Relations*, gave a summary of surveys of 500 plans of employee representation made by him during the past few years.

Mr. Frey attributed 81 per cent of the waste in industry to management, 9 per cent to labor, and 10 to subsidiary causes. He believed that the only way waste could be eliminated was for the management, the efficiency engineer, and the workmen to get together to discuss and handle the various problems.

Mr. Hook's paper described the organization and functions of an advisory committee system in force in his organization for many years. He emphasized the importance of a proper understanding of the motives actuating the management of the business, and pointed out the benefits to be derived from a coöperative scheme which builds confidence and satisfaction on both sides.

Mr. Calder spoke for an organized representation allowing the worker a voice in the management where it touches him most closely. "Most workers," he stated, "want to count in management solely when their personal interests are concerned, and he is a wise manager who begins industrial relations there."

American Gear Manufacturers' Association

Progress in the standardization of gears, as evidenced by reports presented at the seventh annual meeting of the American Gear Manufacturers' Association, held in Cleveland, April 19–21, 1923, is indicative of a great deal of study and a fine spirit of coöperation on the part of the members of the standardization committees. One of the most important of these reports was that of the bevel- and spiral bevel-gear committee concerning a new system of bevel gears which has been worked out at the Gleason Works, Rochester, N. Y. The proposed system was adopted by the association as recommended practice for future design.

B. F. Waterman, chairman of the general standardization committee, summarized the work of the various sub-committees. He advocated that the recommendation of the worm-gear committee, which tended to eliminate the great diversity of hob sizes necessitated by the variance in customers' specifications, be tried out for six months, after which definite action might be taken. He announced a recommendation to be submitted by the metallurgical committee, covering the heat treatment of A.G.M.A. steels, and a forthcoming report on the nomenclature of gears. The proposed tentative American standards which have been submitted include gears and pinions for electric railroad service, gray-iron industrial spur gears, specifications for forged and rolled steel for gears, specifications for cast steel for gears, and specifications for brass and bronze for gears. During a general discussion of various phases of standardization, it was urged that the association should standardize tooth curves, that inspection should start with tooth curves, and that tooth forms for large-sized bevel gears should be standardized.

The report of the association's representatives on the A.S.M.E. research committee on gears stated that the special gear-testing machine designed by Wilfred Lewis had been found to warrant development, and that Ralph E. Flanders, of the Jones & Lamson Machine Co., had been authorized to solicit subscriptions from those interested in this research work.

Among the technical papers presented was one on Grinding and Measuring Involute Gear Teeth, by E. J. Lees, Lees-Bradner Co., Cleveland; one by Wilfred Lewis describing the special gear-testing machine of his design; one on Tooth Forms of Automobile Gears after Cutting, Hardening, and Grinding, by K. L. Hermann,

of the Studebaker Corpn., emphasizing that quietness depends upon the accuracy with which gears are cut; and one by S. P. Rockwell, metallurgical engineer, of Hartford, Conn., who was appointed metallurgist for the association. Mr. Rockwell dealt with the determination of grade of steel by observation of the characteristics of the spark when the sample is held against an abrasive wheel, and gave actual demonstrations to show the difference in the spark produced in the grinding operation with the use of samples of different carbon analysis.

Industrial relations, labor shortage, and cost accounting were among other subjects discussed at the meeting. Geo. L. Markland, Jr., of the Philadelphia Gear Works, was elected president to succeed F. W. Sinram, who has held the office since the formation of the organization in 1917. Mr. Sinram was elected honorary president for life.

Progress of Coal-Storage Campaign

One of the first companies to follow the lead of the Connecticut Company in aiding employees to secure their full supply of coal early in the season is the Adirondack Power & Light Co., of Schenectady, N. Y. Upon receipt of the outline of the Storrs Plan from the Federated American Engineering Societies, this company, of which C. S. Ruffner is general manager, sent a communication to all its employees which read in part as follows:

> In districts where this company sells coke from its gas plants a plan will be published offering special inducements to employees and to the public to purchase coke for their next winter's requirments, for delivery during the period from April 1 to September 1.
>
> For all districts there will be made arrangements whereby any employee may submit by April 15 an estimate of his winter fuel needs; the list of such individual orders will be placed with any dealer selected by a committee consisting of the resident manager and two other employees who desire to purchase fuel by this plan. Delivery to be made at the dealer's convenience any time before September 1. When delivery is made the company will, if requested by the employee, pay the dealer in fullf or fuel delivered, and will be reimbursed by deducting that amount from the employee's salary thereafter in equal installments in each of the next four months after delivery. The company will not buy and sell the fuel but will only guarantee cash payments to the dealer, and will carry the account for the employee as above stated.
>
> Under this plan fuel can be purchased at the best possible price, deliveries can be scheduled advantageously, dealers will be influenced to deliver the maximum amounts early in the season, and employees who have been accustomed to buying coal in small lots during the period of highest prices can make substantial savings and be assured of a sufficient quantity of coal when needed and without severe burdens of prepayment. Employees will be encouraged to enlarge their storage facilities to hold their whole winter's requirements.
>
> Nearly 170 employees of the company (about 10 per cent of the total number) have already ordered coal and coke amounting to over 800 tons, the orders being placed with local dealers at current prices.

The Westinghouse Electric & Manufacturing Co. reports that it is making a study of the plan which will be put into operation if found feasible for their organization. Other companies are desirous of developing their own plans, based upon the Storrs Plan.

Meanwhile the F.A.E.S. Committee on Coal Storage has been organizing. Those who have already accepted appointment on the committee are: W. L. Abbott, chief operating engineer of the Commonwealth Edison Co., Chicago, chairman; P. F. Walker, dean of engineering, University of Kansas; S. W. Parr, professor of applied chemistry, University of Illinois; H. Foster Bain, Director of the U. S. Bureau of Mines, and L. E. Young, Union Light Power Co., St. Louis.

The chairman of this committee has had large experience in the successsful storage of coal, having collaborated with Dr. Stock in much of his pioneer work. Professor Parr and Mr. Young had also worked extensively with Dr. Stock in developing ways and means of effective storage of coal. Professor Parr has a national reputation as a coal chemist. Mr. Young has had wide and responsible engineering experience and is also accomplished in accounting and economics. Dean Walker is especially familiar with the transportation and industrial conditions that will enter into this study. Dr. Bain, as Director of the Bureau of Mines, is in intimate touch with all that the Government has done with this subject.

A bibliography of the subject is already in course of preparation, as well as a compilation of data and records that have already been made by other organizations that will relate to this subject in various ways.

LIBRARY NOTES AND BOOK REVIEWS

American Petroleum Refining. By H. S. Bell. D. Van Nostrand, New York, 1923. Cloth, 6 × 9 in., 456 pp., illus., diagrams, $5.

The first American book exclusively devoted to refining. Discusses the manufacturing process, the arrangement of refineries, the apparatus and treatment used, the storage and transportation of oil, etc. Intended to give the fundamental information needed by those about to erect refineries or by those engaged in the industry who wish a picture of it as a whole.

Automotive Repair. Vol. 3, For Battery Service Men; vol. 4, For Tire Service Men. By J. C. Wright. John Wiley & Sons, New York; Chapman & Hall, London, 1923. Cloth, 6 × 9 in., vol. 3, 387 pp.; vol. 4, 305 pp.; illus., tables, $3 each.

These two volumes complete this extensive work on the repair of automobiles by presenting methods for repairing tires and batteries. They follow the plan of the earlier volumes in giving for each job, first, an outline of the necessary operations, then the materials, tools and parts required and, finally, a detailed description of the method. The reasons for each operation are also given. The directions are clear and practical, and cover almost every emergency that can arise.

Die Dampfturbinen. Vol. 1; Theorie der Dampfturbinen. By Const. Zietemann. Walter de Gruyter & Co., Berlin and Leipzig, 1923. Boards, 4 × 6 in., 150 pp., diagrams, $0.25.

The first portion of a three-volume work on steam turbines which is intended to give not only the theory and thermal calculations, but also practical information on design and construction, and an account of present practice. The work is designed as a concise introduction for students and practicing engineers.

The present volume is concerned chiefly with theory. The fundamental laws of heat, the properties of steam and its flow through orifices are explained. The utilization of the energy of steam in turbines, including methods of reducing speed, is next considered, and this is followed by a discussion of losses in the turbine, efficiency, and power. The final section treats of steam, heat, and fuel consumption.

Elektrotechnik. Vol. 4; Die Erzeugung und Verteilung der Elektrischen Energie. By Immanuel Hermann. Walter de Gruyter & Co., Berlin and Leipzig, 1923. Boards, 4 × 6 in., 138 pp., illus., diagrams, $0.25.

One of a series of small volumes giving an outline of electrical engineering in greatly condensed form. The present volume is concerned with the generation and distribution of electricity and discusses in five chapters power plants, methods of distribution, switch apparatus, distributing networks, and the cost of electric power.

Elements of Applied Physics. By Alpheus W. Smith. First edition. McGraw-Hill Book Co., New York and London, 1923. Cloth, 6 × 9 in., 483 pp., illus., diagrams, $3.

Prepared for students who are primarily interested in the practical applications of physics, this book has been written with their training and habits of thought in mind and includes those topics that they can assimilate thoroughly. A large number of illustrations of the applications of physics to engineering and every-day life are given in an effort to stimulate the student to recognize the universality of physical laws and to find in them the explanation of every-day experiences.

Flussigkeitsbehalter. Rohren, Kanale. Vol. 5, Handbuch fur Eisenbetonbau. By F. Emperger. Third edition. Wilheim Ernst & Sohn, Berlin, 1923. Paper, 7 × 11 in., 409 pp., illus., diagrams, tables. $3.24.

Volume 5 of Emperger's well-known handbook has reached the third edition. It contains two chapters, one upon tanks for liquids, the other upon pipes, open conduits, aqueducts, and canal bridges. The first of these chapters has been entirely rewritten by Dr. Löser, Dr. Grun and Dr. Lewe. It now includes the experience resulting from the extended use of concrete tanks for many purposes since the appearance of the second edition in 1910. The composition of waterproof concrete, waterproofing compounds and paints, and the chemical effects of various liquids are discussed in detail. Similar detailed attention is given to the statics of tank construction, where an attempt is made to set forth modern methods of calculation in an easily understood form and to illustrate them by numerous examples. The chapter on pipes and conduits has been thoroughly revised by F. Lorey, in the light of recent experience and modern structures.

Four Lectures on Relativity and Space. By Charles Proteus Steinmetz. First edition. McGraw-Hill Book Co., New York and London, 1923. Cloth, 6 × 9 in., 126 pp., diagrams, plates in pocket, $2.

In these lectures the extensive use of mathematics has been avoided. Dr. Steinmetz has attempted to give the layman and the engineer who is not an expert mathematician a general knowledge and understanding of the new ideas of time, space, the laws of nature and the characteristics of the universe which the relativity theory has deduced, and of the researches on which the theory rests.

Gas und Wasserversorgung der Gebaude. By Wilhelm Schwaab. Walter de Gruyter & Co., Berlin and Leipzig, 1923. Boards, 4 × 6 in., 121 pp., illus., $0.25.

The purpose of this little volume is to give those interested in gas and water installations in buildings a concise bird's-eye view of the subject. The first division of the work treats of gas, describing its manufacture, the method of distributing it and of installing the piping in the building, and its use for lighting, heating, etc. The second section of the work discusses the water supply in a similar way.

Handbook of Business Correspondence. By S. Roland Hall. McGraw-Hill Book Co., New York and London, 1923. Fabrikoid, 5 × 8 in., 1048 pp., illus., $5.

A small encyclopedia for advertisers and for business men generally, by an experienced manager of sales. Describes the organization of a mail-sales division, methods of caring for dictation, processes for printing and reproducing letters. Gives advice on the composition of letters for various purposes—selling, collecting, adjusting, etc.,—or to various kinds of people, and illustrates this advice by numerous models.

Handbook of Steel Erection. By M. C. Bland. First edition. McGraw-Hill Book Co., New York and London, 1923. Fabricoid, 4 × 7 in., 241 pp., tables. $5.

A pocketbook for engineers and contractors. Section one reviews briefly the ordinary methods for erecting bridges, buildings, standpipes and other structures. Section two, on equipment, contains numerous examples illustrating the design of ordinary appliances and data for finding the wheel and outrigger loads of locomotive cranes and derrick cars. Section three gives the detailed computations for several representative problems in the erection of bridges and buildings. Section four consists of mathematical tables.

Heizung und Luftung. Vol. 1; Das Wesen und die Berechnung der Heizungs- und Luftungsanlagen. By Johannes Körting. Walter de Gruyter & Co., Berlin and Leipzig, 1922. Boards, 4 × 6 in., 139 pp., diagrams, $0.25.

A concise guide for students of heating and ventilation. Deals with theoretical principles, rather than practical details.

History of the Theory of Numbers. Vol. 3, Quadratic and Higher Forms. By Leonard E. Dickson. Carnegie Institution of Washington, Washington, D. C., 1923. Paper, 7 × 10 in., 313 pp., $3.25.

The third volume of this exhaustive history treats of the arithmetical theory of forms and is concerned mainly with general theories rather than with special problems and special theorems. The investigations here in question are largely those of leading experts and deal with the most advanced parts of the theory of numbers. Many of the papers are so recent that all previous reports and treatises are entirely out of date. Every effort has been made to make the list of references complete.

Industrial Furnaces. Vol. 1. By Willibald Trinks. John Wiley & Sons, New York; Chapman & Hall, London, 1923. Cloth, 6 × 9 in., 319 pp., diagrams, $4.50.

This volume deals with the fundamental principles that underly all industrial heating operations and furnace design, and with those applications which are independent of the kind of fuel or energy supply. The principal subjects discussed are the heating capacity and fuel economy of furnaces, heat-saving appliances in combustion furnaces, furnace strength, and durability, and the movement of gases in furnaces. A succeeding volume will treat of specific applications of furnaces.

The book is based on articles published in the *Blast Furnace and Steel Plant* and the *American Drop Forger*, revised and expanded.

Industrial Organic Chemistry. By Samuel P. Sadtler and L. J. Matos. Fifth edition. J. B. Lippincott Co., London and Philadelphia, 1923. Cloth, 6 × 9 in., 691 pp., illus., diagrams, tables, $8.

The fifth edition of this well-known treatise follows the general plan of the preceding ones, but it has been thoroughly revised and to a considerable extent rewritten. Within a single volume of moderate size, it takes up a number of the more important industries or groups of industries based upon organic chemistry, and shows the existing conditions in them. This is done in language that can be understood even by those who are not specially trained in chemistry.

In taking up the several industries, the raw materials are first enumerated and described. The processes of manufacture are then outlined and explained, and the intermediate and final products are characterized. The analytical tests and methods used to control the processes or to determine the purity of the products are then given. A bibliography is appended to each chapter.

Industrial Organization. By Malcolm Keir. Ronald Press, New York, 1923. Cloth, 6 × 9 in., 421 pp., $2.75.

The author of this work believes that many persons find economics difficult and uninteresting because they have little conception of the complex industrial order by which the ordinary necessaries of life reach the consumer or of the complete organization of our national business life. This interesting volume is intended to supply such a background of facts about our industrial organization, to present a picture in perspective of the interlocking factors of our industrial life, and thus to make it possible for the reader to understand and appreciate theoretical economics.

Nickel. By F. B. H. White. Isaac Pitman & Sons, London and New York, 1923. (Pitman's Common Commodities and Industries.) Cloth, 5 × 7 in., 118 pp., illus., tables. $1.

A brief account of the occurrence of nickel, the methods for recovering and refining it, and the uses of the metal and its alloys. Written in simple style and intended for readers who are not specialists, but who wish general information.

Printing Telegraph Systems and Mechanisms. By H. H. Harrison. Longmans, Green & Co., New York and London, 1923. (Manuals of telegraph and telephone engineering.) Cloth, 6 × 9 in., 435 pp., diagrams, $7.

Intended as a reference book for designers of telegraph machinery and as a textbook for those engaged in telegraphy, this book is a comprehensive study of the principles and mechanisms which are involved in p inting telegraphs and a history of the development of the art.

Railroad Freight Transportation. By L. F. Loree. D. Appleton & Co., New York and London, 1923. Cloth, 5 × 8 in., 771 pp., illus., diagrams, map. $5.

All of the functions of a railroad arise from and focus in transportation. As they have become highly specialized, the functions of each department have found exposition in many books. But no book has been written immediately concerned with transportation, the reason for the existence of the railroads. It is the purpose of

this book to assemble in reasoned order all of the phases of loading, distribution of cars, movement of engines and trains, handling of men, the features of permanent way and shop plant, the organization through which they are controlled, and the accounting made of their activities—as they are related to transportation. It is concerned with all that enters into freight transportation.—*Preface.*

SEWERAGE: The Designing, Constructing and Maintaining of Sewerage Systems and Sewage Treatment Plants. By A. Prescott Folwell. Ninth edition. John Wiley & Sons, New York; Chapman & Hall, London, 1922. Cloth, 6 × 9 in., 477 pp., illus., diagrams, tables, $4.

Intended as a reference book for city engineers and as a textbook for students. The present edition has been revised to include new developments since the publication of the eighth edition, while at the same time the space devoted to methods that are disappearing has been reduced. The volume includes a list of all the plants for treating sewage in the United States.

THERMODYNAMICS AND THE FREE ENERGY OF CHEMICAL SUBSTANCES. By Gilbert Newton Lewis and Merle Randall. McGraw-Hill Book Co., New York and London, 1923. Cloth, 6 × 9 in., 653 pp., tables. $5.

The authors have attempted to meet the needs of three classes of readers: first, the beginner who wishes to learn what thermodynamics is and what kinds of problems in physics, chemistry and engineering can be solved by its aid; second, the reader who looks for the philosophical implications of such concepts as energy and entropy; third, the investigator who seeks the specific thermodynamic methods which are applicable to the problem of pure or applied science which he has attacked and the data required for its solution. The book is not a textbook in the ordinary sense of the word, although the authors trust that it will be useful in advanced chemical courses. It is designed rather as an introduction to research and as a guide to anyone who wishes to use thermodynamics in productive work.

WAVELENGTH TABLES FOR SPECTRUM ANALYSIS. By F. Twyman. Adam Hilger, London, 1923. Cloth, 6 × 9 in., 106 pp., tables, 7s. 6d.

This book is a collection of wave-length tables intended for use in the laboratory and containing only matter essential for this purpose. It is of a convenient size and weight. It includes standard wave-lengths from 2375 to 8495 I.A., the persistent and sensitive lines of most of the elements arranged under the names of the elements, and the most persistent and sensitive lines rearranged in order to wave-lengths. There is also a list of wavel-engths useful in the determination of stellar radial velocities. The values are from the most competent authorities and the source of each is carefully indicated.

Important to A.S.M.E. Members Interested in Stress Analysis

AT THE 1922 Annual Meeting, under the auspices of the Railroad Division, an extremely valuable paper dealing with stresses in locomotive frames was presented by R. Eksergian. The paper gives a lengthy and complete discussion of the analytical methods to be followed in determining stresses in locomotive frames.

In view of the fact that there was a great wealth of material presented at the last Annual Meeting and that the Committee on Publication and Papers was compelled to reduce the size of Transactions to the minimum, it was decided to omit Mr. Eksergian's paper from the annual volume, but to print pamphlet copies of the complete paper with the discussion on it, and supply copies to members who might desire to have them. The number of copies printed will be limited to the number of requests for it received before September 1. Requests for this pamphlet should therefore be sent to the Secretary's office before that date.

A synopsis of the paper follows. Members of the Society are requested to study this carefully and determine whether the subject-matter would be of value in their work. It may be stated that the analytical methods developed by Mr. Eksergian should prove of value to all engineers engaged in the study of stresses howsoever set up.

SYNOPSIS OF R. EKSERGIAN'S PAPER ON STRESSES IN LOCOMOTIVE FRAMES

This paper is essentially a preliminary analysis of the major reactions brought on a locomotive frame, as well as of the nature of frame action as regards variation of bending moment, shear, etc., for differently supported types of frames.

A careful analysis has therefore been made of the various methods of equalization, spring design, and the nature of cab supports in electric locomotives. This is followed by a section dealing with the dynamics of the steam locomotive, where the variation of torque and a quantitative investigation of the various oscillations are discussed in detail. Further, a careful analysis of the variation of side-rod loads and journal-bearing loads is included. The succeeding section deals with electric-locomotive drives and the major reactions brought on the frame. This section includes the dynamics of the electric side-rod drive, which discussion augments the previous one on side-rod loads in steam locomotives. The next section discusses the dynamics of braking, its change in load on the equalization and the reactions brought on the frame. In this section is included a brief discussion of bumping loads and dynamical loads on the drawbar.

For a more quantitative investigation of the effects of vertical loads the bar frame has been approximately treated as a continuous beam under equalizer-applied loads and boiler supports, and the variations of bending, shear, etc., for the U. S. Standard Pacific locomotive are computed in detail in Appendix No. 1. Following this is a careful analysis of the stresses resulting from longitudinal loads due to traction, etc.

Finally, the nature of the lateral reactions and the dynamics of lateral oscillations on entering a curve, etc., are discussed, a short recapitulation of the static reactions while on a curve being also given.

A brief outline of methods of analysis coördinating with future experimental work is discussed in Appendix No. 2.

U. S. Navy Crane Ship No. 1

(Continued from page 341)

ends of a cross-shaft supported in bearings in the housings. This shaft is driven by two 110-hp. General Electric type M.B. No. 107 motors to which it is geared by two reductions of spur gearing and one herringbone reduction. The motor shaft is between the motors and is driven by separate pinions meshing with a single gear. A flexible coupling connects the pinions to the motor, and each pinion is provided with a magnetic disk brake.

The upper screws thread through nuts attached to the crane jibs while the lower nuts are carried in the back stays. All nuts are trunnion mounted, and the lower nuts are so arranged that their trunnion bearings are rigidly locked in position when the jib is raised off the cradle; but as the jib is lowered to its seagoing position, these bearings unlock automatically and the nuts slide off so that no possible tension or compression can be set up in the screws due to weaving of the ship. All of the movements of this mechanism are supplied with limit switches which prevent overtravel. A lever-operated band brake controlled from the operator's cab is attached.

The foregoing account is based on information kindly supplied to MECHANICAL ENGINEERING by the office of Rear-Adm. J. W. Beuret, Bureau of Construction and Repairs, Navy Department, Washington, D. C., officers of the League Island Navy Yard, Philadelphia, Pa., and by the Wellman-Seaver-Morgan Company Cleveland, Ohio, builders of the crane.

Discussion on Orifice Coefficients

(Continued from page 348)

the plane of the orifice the true pressure could be obtained at any geometrical point of the given pipe. Similarly, by extending the various curves on Fig. 5 the coefficient for any geometrical point close to or at the plane of the orifice could be obtained. He could see no reason why the most reliable position for pressure taps was in the plane of the orifice.

Mr. Hodgson had referred to the theory of dynamical similarity as applied to orifices in various sizes of pipes. Mr. Pigott had also referred to it, stating that Dr. Buckingham had predicted the characteristics of the orifices and the behavior of the jet at the various geometrical distances as found by the test. Obviously more tests would have to be run on various sizes of pipes before the validity of the geometrical similarity would be established.

THE ENGINEERING INDEX

(Registered United States, Great Britain and Canada)

Exigencies of publication make it necessary to put the main body of The Engineering Index (p. 115-EI of the advertising section) into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.

AIRPLANE ENGINES

Wright. Wright-Navy Development Work Yields Great Increase in Engine Life, B. G. Leighton and R. M. Parsons. Automotive Industries, vol. 48, no. 17, Apr. 26, 1923, pp. 928–931, 2 figs. Changes in valves, valve seats, cylinder design and bearing metal multiply durability and render overhauls much less frequent. Results of tests completed on Wright E-2 model by Bur. of Aeronautics, Navy Dept.

AIRPLANES

Fokker. Fokker F 5 Commercial Transport. Aerial Age, vol. 16, no. 5, May 1923, pp. 218–219 and 232, 3 figs. May be flown as biplane or monoplane by simple expedient of attaching or removing lower wings.

ALCOHOL

Fuel. Alcohol Yields Higher Thermal Efficiency Than Other Fuels. Automotive Industries, vol. 48, no. 16, Apr. 19, 1923, pp. 876–877. Tendency to preignition is noted with 7 to 1 ratio; increase in water content up to 10 per cent is advantage especially under high compressions; no corrosion in engine. From interim report of Brit. Empire Fuels Committee.

AUTOMOBILE ENGINES

Tappet Lever, Positioning. Proper Positioning of Tappet Lever Lessens Valve Mechanism Wear, Glenn D. Angle. Automotive Industries, vol. 48, no. 17, Apr. 26, 1923, pp. 925–927, 9 figs. Correct layout with respect to end and axis of valve stem results in reduction of sliding motion; pure rolling action a prime requisite; question of material of secondary importance.

AUTOMOBILES

Citroën-Kegresse. Crossing the Sahara by Motor Car Engineer, vol. 135, no. 3511, Apr. 20, 1923, pp. 414–415, 9 figs. Account of journey across Sahara Desert and return of four Citroën cars mounted on Kegresse flexible tracks.

BELTING

Leather. How a Leather Belt Transmits Power, J. Edgar Rhoads and R. R. Tatnall. Am. Mach., vol. 58, no. 17, Apr. 26, 1923, pp. 629–631, 3 figs. Factors affecting power transmission; forces acting on belt; effect of centrifugal action on running belt; change in length, creep and slip.

BOILER OPERATION

Temperature and Draft Measurements. The Control of Boilers by Temperature and Draught Measurements, John B. C. Kershaw. Engineer, vol. 135, no. 3513, Apr. 27, 1923, pp. 437–441, 14 figures. Author directs attention to interdependence of tests results for CO_2, temperature and draft; and describes some of latest indicating and recording instruments for making latter type of measurements.

CARS, FREIGHT

Six-Wheel Truck. The Boyden Six-Wheel Coordinating Truck. Ry. Age, vol. 74, no. 20, Apr. 21, 1923, pp. 993–995, 6 figs. Designed to provide extreme flexibility in order to minimize curve resistance and flange wear.

CAST IRON

Hardness Control. Controlling Cast Iron Hardness, S. J. Felton. Iron Trade Rev., vol. 72, no. 19, May 10, 1923, pp. 1382–1383. Metallographic study showing different constituents indicates causes of hardness; control methods; close-grained iron not apt to be porous but has large internal shrinkage.

CENTRAL STATIONS

Birmingham, England. The Nechells Power Station of the Birmingham Corporation, W. Noble Twelvetrees. Engineering, vol. 115, nos. 2978, 2979, 2982, 2986, 2987 and 2989, Jan. 26, Feb. 2, 16, 23, Mar. 2, 23, 30 and Apr. 13, 1923, pp. 99–102, 136–137, 193–196, 227–228 and 238, 291–294, 353–356, 385–388 and 453–456, 101 figs. partly on supp. plates. Permanent generating station designed for ultimate capacity of 100,000 kw.; main power-house buildings comprises boiler and engine house and adjoining building, details of which are given.

CONVEYORS

Moist Fuels. Moist Fuels Present Unusual Conveying Problems, Zuce Kogan. Power Plant Eng., vol. 27, no. 9, May 1, 1923, pp. 461–463, 5 figs. Characteristics of various conveying systems which have been used with success around power plants.

CORROSION

Metals. Corrosion of Metals. Engineer, vol. 135, no. 3512, Apr. 20, 1923, pp. 412–413, 1 fig. Corrosion of industrial metals; influence of heat treatment; heat- and acid-resisting properties of certain nickel-chromium and nickel-chromium iron alloys; Monel metal; dry corrosion; stainless silver. Review of papers presented before joint meeting of Faraday Soc., Inst. of Metals and Manchester Met. Soc.

DIE CASTING

Dies. Design of Die-casting Dies, Charles Pack. Machy. (N. Y.), vol. 29, no. 9, May 1923, pp. 714–716, 2 figs. Discusses cause and elimination of blowholes in die castings; importance of proper venting; factors influencing cost of die casting; factors affecting life of dies.

DROP FORGING

Practice. Drop Forging Practice, Leslie Aitchison. Forging & Heat Treating, vol. 9, no. 4, Apr. 1923, pp. 176–181, 6 figs. Discusses principles which determine size of bar or billet to be used for manufacture of drop forgings; preliminary forging operations.

ELECTRIC FURNACES

Acid. Acid Electric Steel Furnace Operation, J. M. Quinn. Iron Age, vol. 111, no. 17, Apr. 26, 1923, pp. 1177–1179. Iron oxide a controlling factor; its reduction from acid slag; method of charging scrap.

ENGINEERS

Employment Service. Suggestions for An Engineering Employment Service, Morris L. Cooke. Eng. News-Rec., vol. 90, no. 19, May 10, 1923, pp. 830–831. Plan proposed for nation-wide paid service under auspices of Nat. Eng. Societies.

FLOW OF AIR

Measurement. The Measurement of Air Flow, R. O. King. Engineering, vol. 115, nos. 2990 and 2991, Apr. 13 and 20, 1923, pp. 456–458 and 481–482, 6 figs. Measurement of air flow by means of throttle plate with special reference to measurement of air supply to internal-combustion engines.

FLYING BOATS

Dornier Twin-Engined. The Dornier "Wal" Twin-Engined Flying Boat. Aviation, vol. 14, no. 17, Apr. 23, 1923, pp. 444–445, 7 figs. All-metal seaplane for long-range scouting and bombardment work has powerful armament.

FOUNDRIES

Methods and Equipment. Foundry Operates Efficiently, Pat Dwyer Foundry, vol. 51, no. 8, April 15, 1923, pp. 289–297, 16 figs. Practice and equipment at Ferro Machine & Foundry Co., for production of Automobile-engine cylinders. See also Iron Trade Rev., vol. 72, no. 17, Apr. 26, 1923, pp. 1225–1231, 9 figs.

GAGES

Inspection. Gage Inspection Methods, Fred R. Daniels. Machy (N. Y.), vol. 29, no. 9, May 1923, pp. 702–705, 8 figs. Use of high-grade measuring equipment for inspection of small tools.

GRINDING MACHINES

Automatic. Automatic Grinding Machines, Ethan Viall. Am. Mach., vol. 58, nos. 16 and 17, Apr. 19 and 26, 1923, pp. 577–580 and 613–616, 16 figs. Apr. 19: Types of machines; methods of holding and feeding work; kinds and speeds of wheels; stock removed and rate of production. Apr. 26: Centerless grinding; grinding tapered work on centerless machine.

HANDLING MATERIALS

Sugar Refinery. Materials Handling in a Modern Sugar Refinery, Homer L. Rank. Indus. Management (N. Y.), vol. 65, no. 5, May 1923, pp. 306–313, 11 figs. Describes methods and equipment employed in plant of American Sugar Refining Co. at Baltimore.

HELICOPTERS

Oehmichen-Peugeot. The Oehmichen-Peugeot Helicopter. Aviation, vol. 14, no. 15, Apr. 9, 1923, p. 399. Consists of framework of duralumin tubing, forming cross with unequal arms; stabilizing apparatus consists of gyroscope fixed to shaft of motor and turning at maximum peripheral speed of 130 m. per sec.; horizontal propulsion and control.

INDUSTRIAL MANAGEMENT

Executives, Duties of. The Ways and Means of the Chief Executive, John H. Williams. Taylor Soc.—Bul., vol. 8, no. 2, Apr. 1923, pp. 53–58. Discusses subdivision of duties and responsibilities on basis of function or personality of executive; lodging of final authority in committees or individuals; centralization or decentralization of authority; use of acummulated experience or of research as measure of accomplishment; meeting of conditions as they arise or seeking to forecast and prepare for them in advance.

Methods and Principles. Management Methods and Principles of Frank B. Gilbreth, Inc., K. H. Condit. Am. Mach., vol. 58, no. 18, May 3, 1923, pp. 665–666, 2 figs. Function of management engineer to reduce costs, raise wages, increase profits; seeing that workmen has material to work on; principles of blank-form construction.

Rate Setting. Setting Piece Rates by Formula, Chart and Slide Rule, Donald Ross-Ross. Indus. Management (N. Y.), vol. 65, no. 5, May 1923, pp. 301–305, 6 figs. Method worked out by author on certain specific rate-setting problems, but charts and slide rule described lends itself to wide variety of operations.

Routing Work in Foundry. Routing Work in the Steel Foundry, Larry J. Barton. Iron Age, vol. 111, no. 17, Apr. 26, 1923, pp. 1170–1172, 7 figs. System of records designed to prevent harmful leaks; orders filled completely and according to promise.

INTERNAL-COMBUSTION ENGINES

Exhaust Mufflers. Conquering the Noise, Hiram P. Maxim. Power, vol. 57, no. 17, Apr. 24, 1923, pp. 630–633, 7 figs. Results of experiments in developing silencer for firearms; describes construction of exhaust muffler.

IRON CASTINGS

Annealing. Critical Temperatures for Annealing Gray Iron, Emil Schuz. Forging & Heat Treating, vol. 9, no. 4, Apr. 1923, pp. 182–185, 6 figs. Influence of phosphorus and graphite on hardness; importance of pearlite; examples of cementite decomposition; procedure for determining critical temperature. Translated from Stahl u. Eisen, Sept. 18, 1922.

LABOR

Classification. Labor Classification and Pay-Roll Analysis, Carleton F. Brown. Taylor Soc.—Bul., vol. 8, no. 2, Apr. 1923, pp. 69–75 and (discussion) 75–77, 2 figs. Describes method tested, tried and found satisfactory by Corona Typewriter Co.

LOCOMOTIVES

Valve Gears. The Caprotti Locomotive Valve Gear. Engineering, vol. 115, no. 2991, Apr. 27, 1923, pp. 522–523, 17 figs. partly on supp. plate. Describes form of gear introduced on Italian State Railways, which is not worked by eccentrics or rods, but by revolving bevel-driven shaft.

MACHINE SHOPS

Ford River Rouge Plant. Ford Principles and Practice at River Rouge, John H. Van Deventer. Indus. Management (N. Y.), vol. 65, no. 5, May 1923, pp. 257–267, 15 figs. Machine-tool arrangement and parts transportation. Parts for 500 Fordson tractors and 8000 cylinder-block castings for Ford cars are machined daily.

MILLING CUTTERS

Stellite. Milling with Stellite Cutters, C. W. Metzger. Machy. (N. Y.), vol. 29, no. 9, May 1923, pp. 717–720, 6 figs. Directions for obtaining best results and highest efficiency in using stellite milling cutters.

OIL ENGINES

Solid-Injection. Solid-Injection Oil Engine Investigations in Sweden, Edvin Lundgren. Power, vol. 57, no. 18, May 1, 1923, pp. 666–669, 4 figs. Account of experimental work of Swedish Diesel designer in development of Hesselman solid-injection oil engine; particular emphasis is laid on fuel atomization tests.

PYROMETERS

Radiation. A New Radiation Pyrometer, D. Flir. Iron Age, vol. 111, no. 18, May 3, 1923, pp. 1302–1303, 7 figs. Portable instrument for measurement of high temperatures manufactured by Siemens & Halske, Berlin, Germany.

RAILWAY SHOPS

Economies. Suggested Economies for the Railroad Shop, L. S. Love. Iron Age, vol. 111, no. 19, May 10, 1923, pp. 1317–1319, 6 figs. What an Eastern line has done to expedite repairs by modifying practices and preparing for needs in advance.

SPRINGS

Oscillations and Fatigue. Oscillations and Fatigue of Springs, Joseph K. Wood. Am. Mach., vol. 58, nos. 2, 3 and 4, Jan. 11, 18 and 25, 1923, pp. 67–70, 113–117 and 155–158, 17 figs. Jan. 11: General cases of vibration; period equation derived with assumed constant load attached to spring; damped vibrations. Jan. 18: Period equations for springs without attached weight; values for helical and flexural springs; general period formula. Jan. 25: Internal friction as chief cause of fatigue; two resistances in hysteresis; overstrain and its practical uses.

STEAM POWER PLANTS

By-Product Power. Huge Savings Possible by the Use of By-product Power, Lewis J. Sforzini. Power, vol. 57, no. 17, Apr. 24, 1923, pp. 624–628, 7 figs. Possibilities of low-pressure turbine; advantage in use of steam engine or turbine for reducing pressures to points below 20-lb. gage when process-steam demand is spread over reasonable number of hours.

WAGES

Premium and Bonus Systems. Premium and Bonus Plans, H. K. Hathaway. Taylor Soc.—Bul., vol. 8, no. 2, Apr. 1923, pp. 59–65. Discusses straight piece-work, Halsey's premium, Emerson's bonus, and task systems; explains Gantt task and bonus system in detail which author believes, is best from standpoint of accomplishment in matter of high production and low cost, and as preventive of misunderstandings and mistrust that are at bottom of most labor troubles.

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Mechanical Engineering

The Monthly Journal Published by

The American Society of Mechanical Engineers

Publication Office, 207 Church Street, Easton, Pa. Editorial and Advertising Departments at the Headquarters of the Society, 29 West Thirty-ninth Street, New York

Volume 45 | July, 1923 | Number 7

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DEPARTMENTAL

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Price 50 Cents a Copy, $4.00 a year: to Members and Affiliates, 40 cents a Copy, $3.00 a Year. Postage to Canada, 75 Cents Additional; to Foreign Countries $1.50 Additional. Changes of address should be sent to the Society Headquarters.

Entered as second class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879
Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921.

Julian C. Smith

Walter F. Rittman

Sumner B. Ely

Frederick A. Gaby

Contributors to This Issue

Sumner B. Ely and **Walter F. Rittman**, co-authors of the leading article in this issue, are former business men now connected with the Carnegie Institute of Technology. Mr. Ely was born at Watertown, N. Y., in 1869, attended the public schools in Chicago, and received his M.E. from the Massachusetts Institute of Technology in 1892. Following graduation he worked as a machinist for various companies.

In 1897 Mr. Ely went into the drafting room of the Pressed Steel Car Co., at Pittsburgh, Pa. While associated with this company he went to Egypt to superintend the erection of the first lot of steel cars shipped there, and in 1902, a year after he became chief engineer of the American Sheet Steel Co., he was sent to Germany to study continuous sheet-rolling methods. The following year, when this company was merged into the American Sheet & Tin Plate Co., he became its assistant chief engineer, and later its chief engineer. In 1905, he organized the Chester B. Albree Iron Works Co., of which he became vice-president. It was not until 1916, after the death of Mr. Albree, that he disposed of his business interests and became assistant professor of commercial engineering at Carnegie.

Dr. Rittman was born at Sandusky, Ohio, in 1883, received his A.B. from Swarthmore in 1908, and entered the business world as chemist for the United Gas Improvement Co. of Philadelphia. In 1909 he opened an office in that city as consulting engineer. For seven years, from 1914 on, he was chemical engineer with the U. S. Bureau of Mines. He became head of the Department of Commercial Engineering at Carnegie two years ago.

Dr. Rittman received his Ph.D. from Columbia, and degrees in chemical and mechanical engineering from his alma mater. Both of these men are members of the A.A.A.S. the A.S.M.E., and other engineering and scientific organizations.

* * * * *

Julian C. Smith, author of the paper on power development in Quebec, was graduated from Cornell as a mechanical engineer in 1900 and began his business career as a draftsman with Wallace C. Johnson, consulting engineer of Niagara Falls, N. Y. Two years later he was made assistant engineer to Mr. Johnson at Shawinigan Falls, Quebec. In 1903 he became superintendent of the Shawinigan Water & Power Co. of Montreal, and was rapidly promoted to his present position of vice-president and general manager, and executive of all subsidiary companies. He is also president of a number of power and public service companies in Canada.

Mr. Smith is a member of the British Institution of Electrical Engineers, the Canadian Society of Civil Engineers, and the A.I.E.E. He was recently given the honorary degree of LL.D. by Queens University, Kingston, Ontario.

* * * * *

Frederick A. Gaby, who has been with the Hydro-Electric Power Commission of Ontario since 1907, its chief engineer since 1912, is a Canadian by birth and is about forty-five years old. He is a Toronto University graduate, year of 1903. Prior to his appointment to the Commission he was with the Canadian General Electric Co., the Toronto Niagara Power Co., and various companies handling electrical installation work.

Mr. Gaby is a fellow of the Royal Society of Arts and of the A.I.E.E., and a member of the A.S.C.E., A.S.M.E., E.I.C., and many other technical organizations in Canada and the United States.

* * * * *

G. G. Bell, who contributed an article on feedwater heating, was graduated from Toronto University in 1905 as an electrical engineer and took a special course in civil engineering two years later. The intervening time he spent in the engineering office of the Canada Foundry Co. of Toronto. From 1908 to 1910 he was engaged in structural drafting and design for the Canadian Bridge Company, Walkerville, Ont., and for a like period of time handled structural and hydraulic engineering for the Sawyer-Moulton Co., Portland, Me. Mr. Bell first became associated with the West Penn Power Co. in March, 1912. He is now manager of power development.

* * * * *

Herbert W. Croizer, with the assistance of J. D. Stigen and C. E. Nagel, tells about Diesel-engine progress on the Pacific Coast. These men are all good Californians now, whatever their nativity. Mr. Crozier was born and educated in that peerless state, being graduated from the University of California in 1899. For eight years he held various positions in electrical and constructional work. During the last fifteen years he has been mechanical and electrical engineer and manager of the San Francisco district for Sanderson & Porter, San Francisco.

For the past four years Mr. Stigen has been naval architect for the Standard Oil Co. of California. Previously he was connected with the Pacific Gas & Elec. Co., and the Union Branch of the Bethlehem Shipbuilding Co.

Mr. Nagel has been chief engineer of the Pacific Diesel Engine Co., Oakland, Cal., for the past three years. He was formerly assistant district supervisor of the Emergency Fleet Corporation at New Orleans, and for ten years prior thereto was state bridge engineer of Minnesota.

Coming A.S.M.E. Events

The Montreal Spring Meeting reported in this issue of MECHANICAL ENGINEERING is the last meeting until Fall. Then will occur the third regional meeting, to be held at Chattanooga, Tenn., October 23-24. The Annual Meeting will be held in New York, December 3-6.

Plans for the Chattanooga meeting include sessions on power, management, and welding. The Annual Meeting program is also well under way and an interesting four days is assured. The A.S.M.E. NEWS will contain the advance information about these events.

MECHANICAL ENGINEERING

Volume 45 July, 1923 No. 7

Power and Fuel Consumption of the Iron and Steel Industries of the Pittsburgh District

By SUMNER B. ELY[1] and W. F. RITTMAN,[1] PITTSBURGH, PA.

THE Carnegie Institute of Technology through its Commercial Engineering Department is conducting a major investigation of present power requirements and potential future power possibilities in the Pittsburgh district (1) with relation to the community and its development as a whole and (2) with relation to the various specific industries of the community.

The largest and most important industrial activity of the district is the production of iron and steel, and the first step has naturally been to make a detailed study of that industry with relation to its power requirements.

Some idea of the quantity of steam used by the steel industry within the 30-mile-radius circle around Pittsburgh can be had from the following interesting comparison with the Superpower Survey for the region between Boston and Washington lately published by W. S. Murray and others. If the boiler horsepower-hours as shown in the Pittsburgh power-study curve for the year 1920 [see curve (*b*), Fig. 2] are put into equivalent kilowatt-hours, it will be found that this figure is about two-thirds of the total kilowatt-hours for the same period as given in the Superpower Survey for the whole district covered by it.

The value of such a survey lies (1) in the importance of the Pittsburgh district as a factor in the nation's steel production, and (2) in the fact that the data will serve as a basis of comparison when corresponding data are collected for other steel centers. Furthermore, any development in the use of or in the creation of power for the steel industry is of vital concern to the other industries of the community, and, in fact, of interest even to concerns located within a radius of 100 miles or more from Pittsburgh. Finally, it was felt that a detailed study of power and fuel consumption in the steel industry in a district as important as that embraced by this investigation would give some indication as to the general trend of developments during the period covered, and there is good reason to believe that this expectation has been justified.

Points Brought Out by the Survey

The data presented show certain marked developments in the power phase of the steel industry. First, they reveal a greatly increased use of given equipment—expressed by the increased load carried by each unit of physical equipment; and secondly, a marked increase in cost of fuel for the development of power, as well as a period of inefficient fuel use coinciding with the war years. The curves drawn from data obtained in this survey indicate the volume and importance of power as a factor in determining steel production costs. A continuation of such curves will register changes in efficiency, while the accurate cost data obtained will undoubtedly be useful for future planning.

The Pittsburgh undertaking has taught a valuable lesson in regard to what might be called the art of making industrial surveys. It is obvious that the value of such a survey is primarily dependent on the ability of those making it to ascertain the facts which shall form the foundation of the deductions later made, and what is perhaps even more important, the ability to ascertain *all* the facts and not merely those easily accessible, and to express them in a comparable manner and in sufficient detail to enable one to obtain a clear insight into their significance.

In this connection it appeared early in the study that some of the institutions investigated either did not have the necessary facts properly collected or were reluctant to give detailed data as to their costs, fuel and power consumption, efficiency and so on, on the ground that their organizations might show up unfavorably in comparison with others, or that because of their size they would be accused of monopoly in their particular branch of the industry.

There was no way of compelling compliance with the request for facts, and even if there had been it would have been probably extremely unwise to have employed it. It was decided that the only way to collect the data was to obtain it from the individual companies, which meant that, speaking colloquially, the idea of the survey had to be "sold" to these companies, and that the various institutions involved had to be instilled with sufficient faith in the Carnegie Institute of Technology to entrust it with this confidential detailed information. This situation was met by a general agreement that no specific data referring to individual companies would be published and that all the data would be used only in combination so that only summation or overall figures would be shown.

In the spirit of confidence and mutual goodwill thus created it became comparatively easy to meet the next obstacle, namely, that different institutions used different units of measure and different ways of keeping records, which made interpretation difficult. This was done by the various parties involved joining about a common table and placing their respective engineers in conference for the common end. For instance, in the case of the public utilities, the data and trends were developed by engineers from the various utilities in counsel with the Carnegie Institute of Technology. There are indications that these conferences and the work done on the survey may lead to a greater completeness and uniformity of power- and fuel-consumption records in the steel industry of the

[1] Professors of Commercial Engineering, Carnegie Institute of Technology.

Pittsburgh district. Further, the work has effectually shown that the community or industrial inventory can be made only with the complete coöperation of the community and industry.

In general, it will be noted that the period covered by the curves presented is one of the most interesting in the history of our country, namely, that of the world war, but with a few overlapping years so that an idea of the trend is given and the distortion produced by the war indicated. Take for example the efficiency curve shown in Fig. 13 (*a*), which indicates how the efficiency of firing fuel varied during the war years and as what occurred in the Pittsburgh district is typical of what took place in most of the manufacturing districts of the United States it is not unreasonable to say that these curves in great measure reflect other manufacturing industries; so that by the study of these curves we can learn something, broadly speaking, of the condition of the whole country.

Again, a tendency to work equipment beyond its capacity is distinctly shown at the beginning of the war—possibly because additional equipment could not be obtained promptly—and later on an increase in equipment is evident. This undoubtedly reflects the general conditions then prevailing in most manufacturing industries, and while this agrees with general opinion, the curves provide a definite, concrete verification.

Furthermore it must not be forgotten that power is approximately proportional to production, and that the curves indicate in general the demand for steel and iron. The general rise in the price of fuel has not been confined to the Pittsburgh district, so that the percentage increase in the cost or price of fuel gives a fairly good idea of what happened throughout the United States, or the eastern half of it at least.

Defining the Pittsburgh District

The corporate limits of the City of Pittsburgh long ago proved inadequate to hold the manufacturing establishments and plants which now spread up and down its rivers and arteries of transportation. They are much more restricted than those of most metropolitan districts, but serve as the hub of the fifth major district of the country and embrace a population of over 1,200,000. The area selected for this study was that of the circle struck with a radius of thirty miles from the Pittsburgh City County Building as the center (see Fig. 1), because the people and the iron and steel plants comprised within it are intimately associated with and largely dependent upon the facilities of corporate Pittsburgh.

Summary of the Data Presented

Naturally a large number of sources of information are used in a study of this character. The various iron and steel interests of the community were most obliging in furnishing the data at their command. In addition, the authors were helped greatly by the Pennsylvania Department of Internal Affairs; by the Interior Department at Washington; by the officials of the American Iron and Steel Institute; and by the various technical journals and publications of the industry.

Table 1 presents the summation data covering the more important items entering into this study. To the business man the figures given in this table are valuable as covering the more important elements and relationships entering into the industry, but to the iron and steel engineer or the power engineer the detailed data and relationships are of equal if not greater interest. Column 1 shows the total gross tons of fuel, coal equivalent, used under boilers; column 2 the cost of this fuel, and column 3 the gross tons of ingots produced with this fuel. The three succeeding columns cover data derived from the first three columns. These data show that as the number of gross tons of steel ingots rose from approximately ten million in 1911 to thirteen million in 1920, the value of the fuel used under boilers increased from less than seven million dollars to more than twenty-nine million. On the other hand, the fuel used per gross ton of ingots produced increased only from 0.57 ton to 0.60 ton, and the value of fuel used per gross ton of steel ingots produced increased from $0.65 in 1911 to $2.27 in 1920.

The Rated-Capacity Curve, Fig. 2 (*a*), represents the boiler capacity of all the iron and steel plants in the District. The curve shows practically no increase in the installed boiler capacity during the years 1914 to 1917, but a tendency in that direction since 1918. In no case has the increase in boiler capacity been in proportion to the increase in production; in other words, increased producing capacity was attained largely by the harder and more efficient use of the existing equipment.

The Output Curve, Fig. 2 (*b*), gives, in boiler horsepower-hours, the total quantity of steam produced per year by the installed rated capacity shown by curve (*a*). By superimposing curve (*b*),

on curve (*a*), the extent to which greater utilization was secured from existing equipment becomes evident.

The Coal Used is shown in Fig. 2 (*c*), and is the tonnage actually fired under the boilers to produce the steam shown by curve (*b*) of the same figure. This curve appears to correspond closely with curves (*a*) and (*b*) in showing a fall in 1914 and then a greatly increased activity through 1920. A pronounced peak is evident during 1918. Personal investigation has developed the fact that much of this increase was not the result of efficient expansion. During that period fireman as a group showed a considerable labor turnover with resultant inefficiency in the use of a given volume of fuel, and considerable coal of less desirable character was used. Facts like these are not shown in the statistics but are of primary importance.

The Total Value of the Coal Used is shown in Fig. 3 (*a*). The rise in this curve from 1915 to 1918 is greater than the rise for the same period in the tonnage curve, Fig. 2(*c*), reflecting that the price per ton was advancing during the period—as might well have been expected from the demand at that time. The total amount of money paid for boiler coal during the year 1920 was in excess of $20,000,000.

The Price of Boiler Coal per gross ton throughout the period is shown in Fig. 4 and was derived by dividing the values of curve (*a*), Fig. 3, by the tonnage volume of curve (*c*) Fig. 2. The price variation during the period is vividly portrayed. A persistent upward tendency running from $0.955 in 1911 to $4.10 per gross ton in 1920 accords with the trend of all commodities during the period.

The Total Blast-Furnace Gas Used under boilers is shown in Fig. 5. In order to have a better basis of comparison, the cubic feet of a gas are expressed in terms of coal equivalent. The ratio used is 103 B.t.u. per cubic foot of gas to 13,500 B.t.u. per pound of coal.

Fig. 1 The Pittsburgh District Studied, which Embraces the Area Within a Radius of Thirty Miles from the City's Center

The Value of the Blast Furnace Gas Used, Fig. 3 (*b*), was estimated by valuing the quantities shown in Fig. 5. Considerable difference of opinion naturally existed as to what this value should be. A few years ago blast-furnace gas, being a by-product, was considered as of small value. Today, however, iron and steel manufacturers distribute a book charge for this gas, generally against the power plant, which is right and proper. The generally-agreed-upon value of the coal equivalent is $1.35 per ton, but in 1920 this figure was changed to $3.27. The weakness of such empirical assumptions is recognized, but so long as the basis of calculation is understood, each reader can revise the conclusions as he may see fit.

The Natural Gas Used under the boilers in the iron and steel industry is shown in Fig. 6 (*a*). The amount consumed was very small, and prior to 1918 was of such small volume as to be negligible.

The Cost of Natural Gas Used under boilers is shown in Fig. 6 (*b*), and during 1919 was only about $3000, an amount so small as to be of little importance in the total figures. The curves show that the average cost of the 18,000,000 cu. ft. used during 1919 was 18 cents per 1000 cu. ft. More natural gas probably would have been used by the industry had it not been for regulations exercised by the producers and distributors of natural gas by which domestic users were given priority.

The By-Product Tar Used as boiler fuel is shown in Fig. 7 (*a*), and, as in the case of the natural gas, was negligible when compared to the total fuel consumed. The tar is expressed in terms of coal equivalent on the ratio of one pound of coal containing 13,500 B.t.u. and one gallon of tar containing 168,000 B.t.u.

The Value of the Tar Used as boiler fuel is shown by curve (*b*) of Fig. 7.

In the Pittsburgh District considerable gas is generated by the by-product coke ovens for use in open-hearth furnaces. At Clairton alone more than 13,000 tons of coal are being coked daily in by-product ovens, and the capacity of this plant is now being doubled. While some of this gas is occasionally diverted to boilers because of shutdowns of furnaces and some is used for what is known as "regulator gas" to take care of slight shortages that may arise, the quantity is so small as to be negligible in the fuel totals for boilers under consideration.

The Total Quantity of Fuel Used under the boilers of the iron and steel manufacturers in the Pittsburgh District is shown in Fig. 8. The upper curve, which represents a summation of the coal, gas, and tar used, has much the same shape as that of the lower one, which covers coal only and is reproduced on a different scale from Fig. 2 (*c*). There was a decided upward trend in the fuel consumption of the industry from 1911 to 1920 which corresponded generally with the increase in iron and steel production during that period.

The Percentages of Coal and Blast-Furnace Gas Used for power purposes are shown in Fig. 9. The curve is based on the coal equivalent for blast-furnace gas as compared with the coal, and appears to be fairly constant in the ratio of 60 per cent coal to 40 per cent gas. This ratio is important because it shows that through the efficient use of the blast-furnace gases they can be substituted for 40 per cent of the coal which otherwise would be required.

The Total Value of All Fuels Used under the boilers of iron and steel manufacturers in the District is shown by Fig. 10. Comparing this curve with curve (*a*) of Fig. 3 which shows the same data for coal only, it will be observed that the proportion and trend in blast-furnace-gas consumption is such as not to materially change the slope of the curve. It clearly brings out the upward trend in the value of power fuel since 1911. Starting at about $5,250,000 in 1911 there was comparatively little change until 1915, when a marked increase occurred during the war years, with a decrease from 1918 to 1919 and a further considerable rise until the value reached more than $29,000,000 in 1920, or an increase of more than 500 per cent during the ten-year period.

The Value of a Unit of Fuel is shown in Fig. 11. This value comprises coal and blast-furnace gas, the natural gas and other fuels being negligible. The curve further shows the proportionate

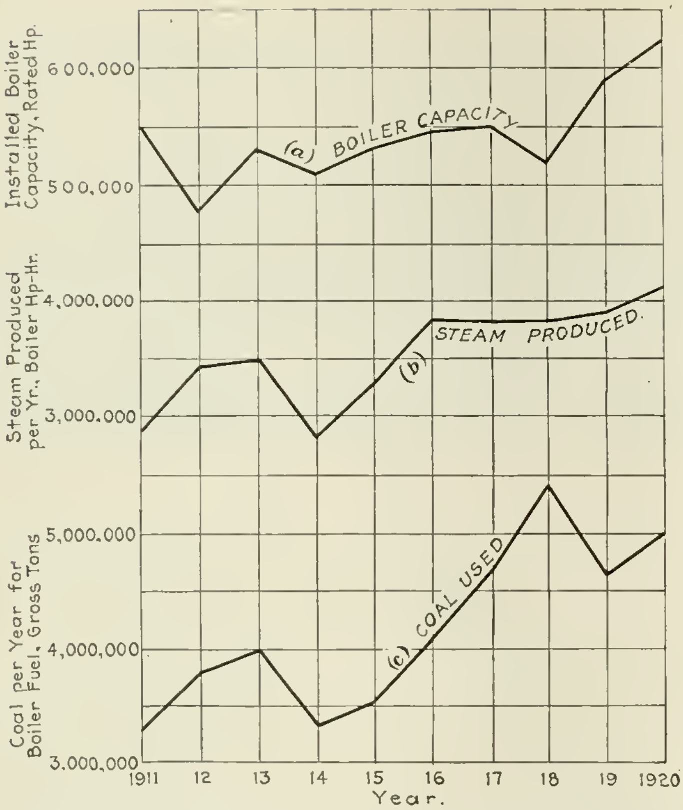


Fig. 2 Curves Showing (a) Total Rated Horsepower Capacity, (b) Total Quantity of Steam Produced, and (c) Coal Used for Boiler Fuel in All Steel Works of the Pittsburgh District

(Note: 1 hp. rated capacity = 10 sq. ft. of heating surface.)

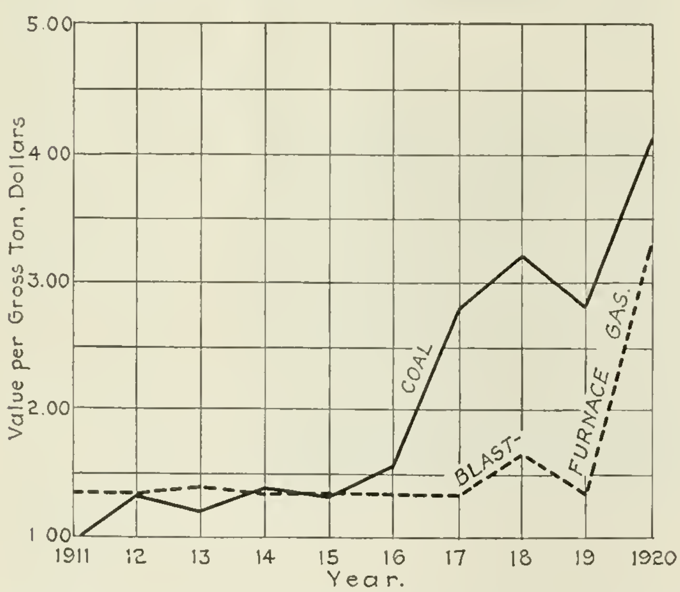


Fig. 4 Curves Showing Value per Gross Ton of Coal and Blast-Furnace Gas Used as Boiler Fuel in All Steel Works of the Pittsburgh District

(Note: Value given for a "gross ton" of blast-furnace gas is for the quantity of gas that will develop the same amount of heat as one gross ton of coal.)

values of coal and blast-furnace gas which go to make up the unit value. The unit taken is a gross ton, the blast-furnace-gas equivalent coal value being used as previously stated.

The percentage shown by Fig. 9 makes the blast-furnace-gas equivalent coal used not greatly less than the actual coal used, whereas the values in dollars show the blast-furnace gas to be valued at a much smaller figure than the coal. This is a question of bookkeeping as before stated. It would seem logical that blast-furnace gas should be given a higher value to make its variations more nearly correspond with the variations in coal prices. In this

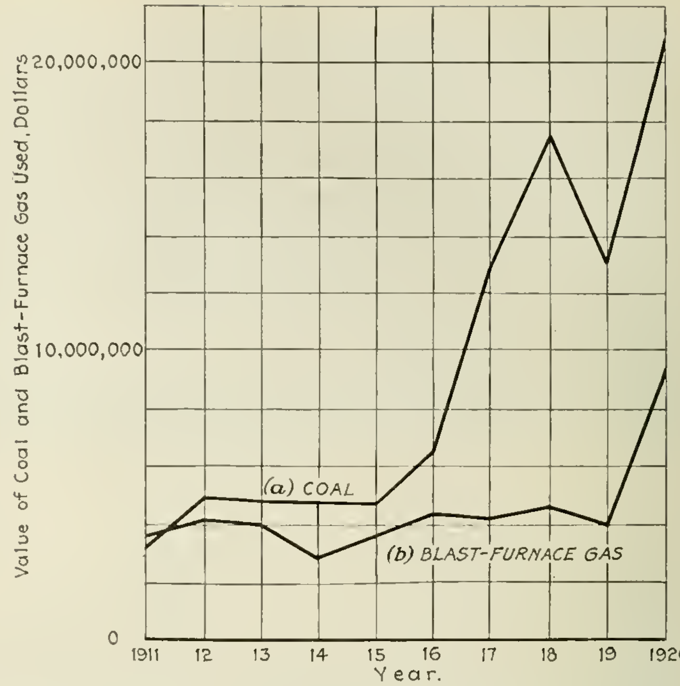


Fig. 3 Curves Showing Value of Coal and Blast-Furnace Gas Used for Boiler Fuel in All Steel Works of the Pittsburgh District

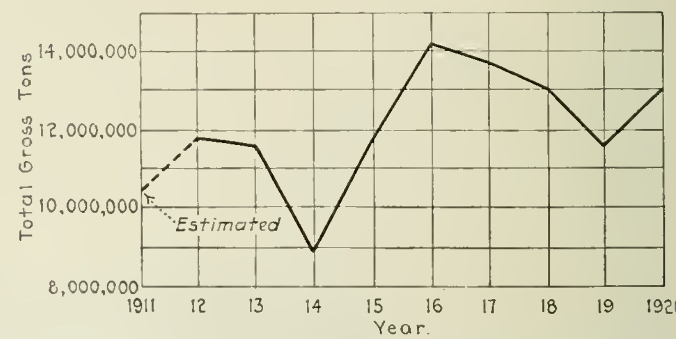


Fig. 5 Curve Showing "Gross Tons" of Blast-Furnace Gas Used for Boiler Fuel in All Steel Works of the Pittsburgh District

(See note under caption of Fig. 4.)

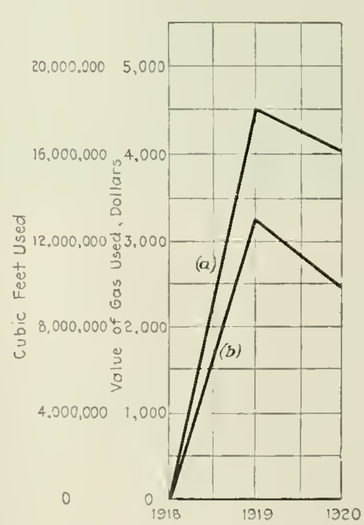


Fig. 6

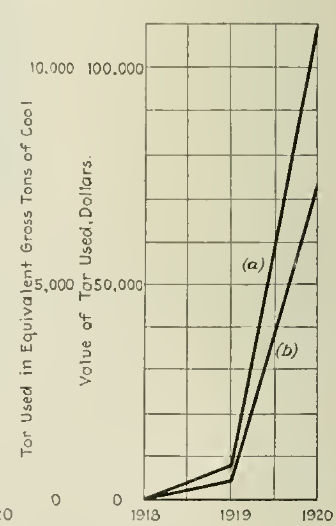


Fig. 7

Fig. 6 Curves Showing (a) Quantity and (b) Value of Natural Gas Used for Boiler Fuel in All Steel Works of the Pittsburgh District

Fig. 7 Curves Showing (a) Quantity and (b) Value of Tar Used for Boiler Fuel in All Steel Works of the Pittsburgh District

(Note: A "gross ton" of tar is the quantity of tar that will develop the same amount of heat as one gross ton of coal.)

TABLE 1 FUEL CONSUMPTION, STEEL PRODUCTION, AND GENERAL DATA ON STEEL WORKS OF THE PITTSBURGH DISTRICT

Year	Gross tons of fuel used under boilers	Value of fuel used under boilers	Gross tons of steel ingots produced	Gross tons of fuel used under boilers per gross ton of steel ingots produced	Value of fuel used under boilers per gross ton of steel ingots produced	Value of one gross ton of fuel used under boilers
1911	5,920,000	$ 6,500,000	10,400,000[1]	0.57	$ 0.65	$ 1.10
1912	6,850,000	9,200,000	11,800,000	0.58	0.78	1.35
1913	6,850,000	9,200,000	11,600,000	0.59	0.79	1.35
1914	5,470,000	7,400,000	8,900,000	0.61	0.83	1.35
1915	6,280,000	8,300,000	11,700,000	0.54	0.71	1.34
1916	7,400,000	10,900,000	14,100,000	0.53	0.77	1.48
1917	7,830,000	17,300,000	13,700,000	0.57	1.26	2.22
1918	8,250,000	21,700,000	13,000,000	0.63	1.67	2.63
1919	7,270,000	17,000,000	11,600,000	0.63	1.47	2.34
1920	7,830,000	29,500,000	13,000,000	0.60	2.27	3.76

[1] Estimated.

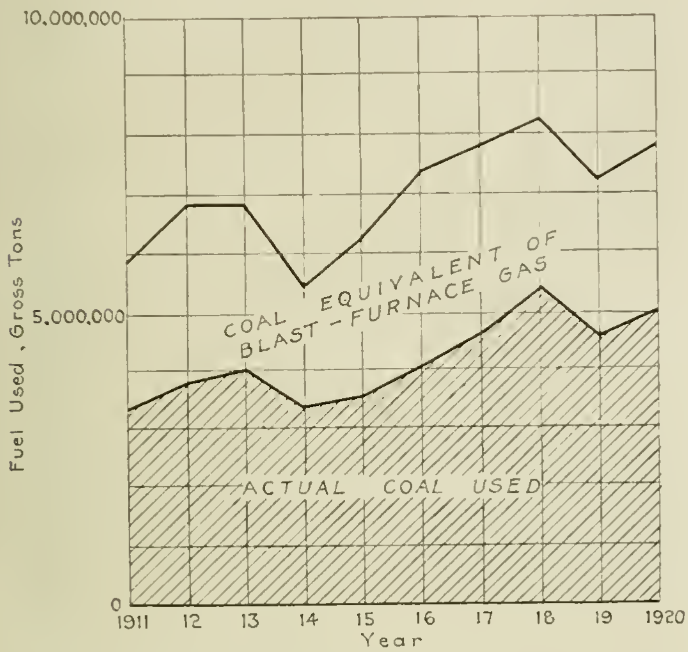


Fig. 8 Curve Showing Total Quantity of Fuel Used Under Boilers in All Steel Works of the Pittsburgh District
(Note: See note under caption of Fig. 4.)

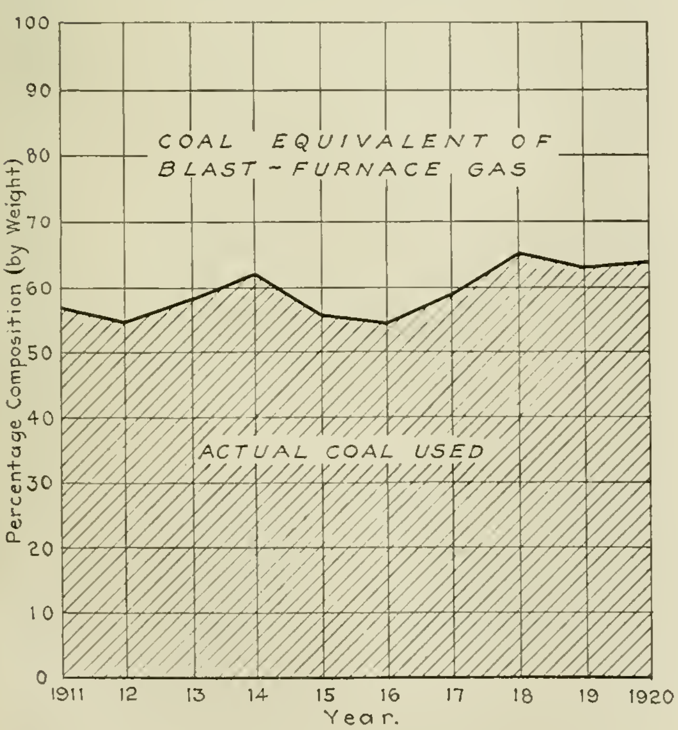


Fig. 9 Curve Showing Percentage Composition (by weight) of the Average Gross Ton of Fuel Used Under Boilers in All Steel Works of the Pittsburgh District
(Explanation: In 1916, e.g., one gross ton of average boiler fuel consisted of 55 per cent coal and 45 per cent blast-furnace gas. See note under caption of Fig. 4.)

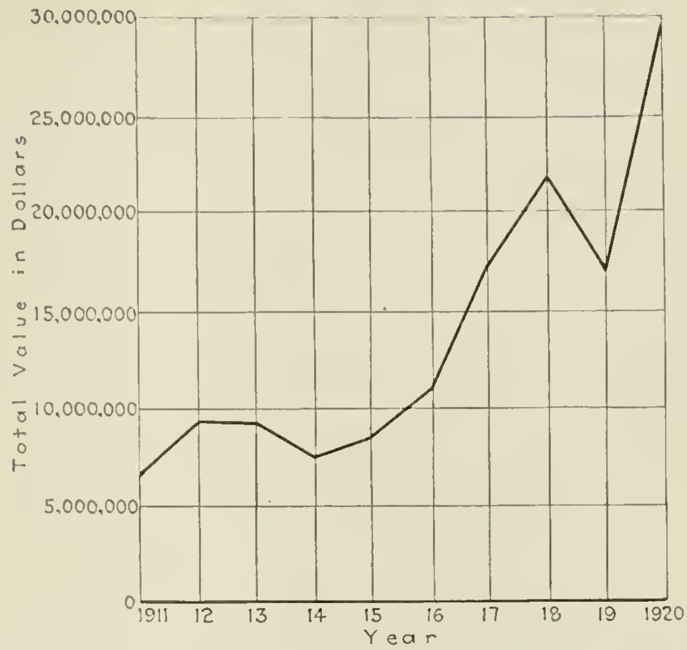


Fig. 10 Curve Showing Value of Fuels of All Kinds Used Under Boilers in All Steel Works of the Pittsburgh District

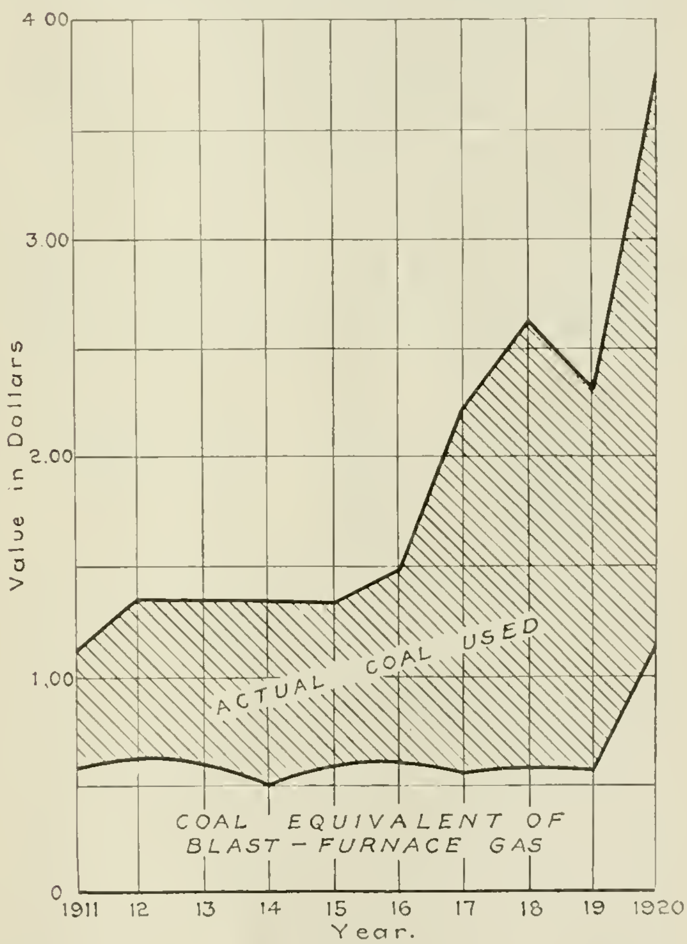


Fig. 11 Curve Showing Value of One Gross Ton of Fuel Used Under Boilers in All Steel Works of the Pittsburgh District
(Explanation: In 1916, e.g., one gross ton of average steam fuel consisted of 61 cents' worth of blast-furnace gas and 87 cents' worth of coal, making the fuel equivalent of one gross ton of coal cost $1.48. See note under caption of Fig. 4.)

study, however, it was considered advisable to follow more nearly the practices of the industry.

The Total Tonnage of Iron and Steel Produced in the Pittsburgh District during the years 1911 to 1920 is taken as the total weight of ingots produced during that period and is given in detail in Table 1, and expressed in the form of a curve in Fig. 12. These figures were

largely derived from the American Iron and Steel Institute for the later years, whereas for the earlier years a canvass was necessary to secure data covering each individual plant in the District.

It was considered advisable to use ingots as a basis of weights in connection with the production of the iron and steel plants, because it was deemed impracticable to use records of finished tonnages since the latter practice inevitably involves much duplication and confusion of data.

The curve as a whole shows a decided upward trend in keeping with the trend in general production. On the other hand, the ten-year period covered is probably too brief a one upon which to base conclusions as to the proportion of increase that the Pittsburgh District is responsible for in the industry as a whole.

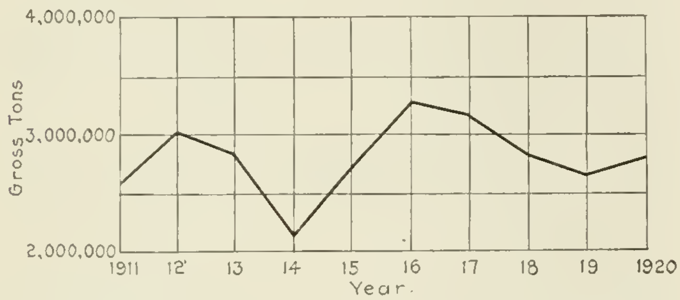


Fig. 12 Curve Showing Total Quantity of Steel Ingots Produced per Year in All Steel Works of the Pittsburgh District

The Quantity of Power Fuel per Ton of Steel is shown by curve (*a*) of Fig. 13. Variation in this curve resulted either from the use of less desirable fuels or variations in the efficient utilization of the fuels available. Details regarding the efficient use of fuels cannot be shown in general-data figures, but are worthy of special study.

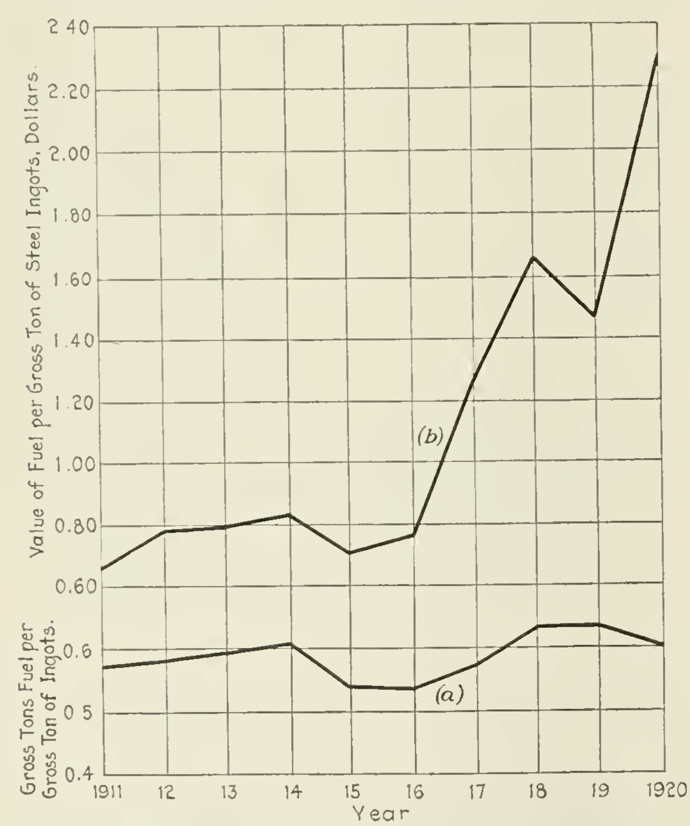


Fig. 13 Curves Showing (*a*) Quantity and (*b*) Value of Fuel (Coal plus Blast-Furnace Gas) Used Under Boilers per Gross Ton of Steel Ingots Produced in all Steel Works of the Pittsburgh District

The Cost of Power Fuel per Ton of Steel is shown by curve (*b*), of Fig. 13, which represents the data of curve (*a*) translated into dollars and cents and indicates how the price of fuel advanced during the latter half of the period. It will be noted that in 1911 the cost of power fuel to manufacture a gross ton of ingots was 65 cents, whereas by 1920 this same figure had mounted to $2.27, an increase of more than 300 per cent.

The data presented show two marked developments in the power phase of the industry: first, the increased load carried by each unit of physical equipment; and second, the marked increase in cost of fuel for the development of power. Many other equally interesting observations and comparisons can be made for the ten-year period, but because of the different viewpoints of those interested in the industry, the authors prefer to leave the wide variety of interpretations possible to such individuals or groups.

FROM the beginning the steel industry has had to depend on its own orgaization for its power, for at the outset there were no adequate sources of, or means of transporting to the plant, the large quantities required, and long before any knowledge of electrical generation and transmission it was recognized that the sources of power in the industry itself necessitated their utilization at the plant, so that we have today in every steel works a power plant, frequently in many units, generating in all of its several phases most of the power required to carry on the various operations from raw materials to finished steel products.

During comparatively recent years tremendous development has been made in the size, reliability, and control of electrical apparatus for steel-plant service, and in the generation and transmission of the power required for its operation. Its almost innumerable applications have been so general in character and large in total that in many cases the development of the plant's own power supply has not kept pace either in economy or size with the peak power demand, so that electric current frequently must be purchased to take care of these maximum-load periods. It is only natural to expect that still further applications of power, both electric and steam, will be made in the ever-constant development of the steel industry so that its power plant will ever become increasingly important.

Unfortunately, power does not appear on our cost sheets as a single total item, and we are apt to think of power costs only to the extent that they do appear as separate items of steam, electricity, water and air, not always remembering that power is the total of all of these, plus the additional power costs that are necessarily included in our cost-sheet figures, in raw materials for their handling, in partly worked materials, power for shops appearing as repairs, and many other auxiliary operations. The result is that the true cost of power is not generally fully appreciated, total power cost being defined as the cost of producing or purchasing all the energy for generating steam, electricity and blast-furnace blowing. In such a cost, waste heat must be accorded a value commensurate with the value of the fuel that would have to replace it if the waste heat were not available.

The author gives a tabulation of cost data taken from the cost records of three of the Bethlehem Steel Company's plants. This tabulation covers the period from Jan. 1, 1920, to Aug. 1, 1922, considered as representative. From this tabulation the importance of the power item in steel making appears plainly.

Any single cost item that stripped of all credits reaches the proportion of early one-fifth of the total plant payroll, or $5^1/_2$ per cent of the total sales value of all manufactured products, or twice the cost of all refractories, commands attention. How to reduce it, and the extent to which it can be reduced, constitute the real economic question.

In general, there are three points of attack on the problem after the cost analysis has been made; first, on the prime movers of mill and auxiliary drives; second, on the electric generating and blast-furnace blowing plants; and third, on the steam plants. For new installations there is little room for argument against electrification as showing the greatest economy. For existing steam-driven units practically every case will show a fair return on the investment by the substitution of electric drive, including the generating equipment.

In general, steelworks have not taken full advantage of the economies possible in connection with the operation of electric generating stations and blast-furnace blowing plants. (Abstract of paper read by E. F. Entwisle, Mem. A.S.M.E., before the *American Iron and Steel Institute* published in *The Iron and Coal Trades Review*, vol. 106, no. 2882, May 25, 1923, p. 784)

Hydroelectric Possibilities of Quebec

The Potential and Actual Hydroelectric Development of the Province of Quebec and Its Probable Rate of Growth in the Future

By JULIAN C. SMITH,[1] MONTREAL, CANADA

THE OBJECT of this paper is to present briefly the potential and actual hydroelectric development of the province of Quebec, and so far as may be done from the progress in the past, to estimate the probable rate of development of the hydroelectric resources in the future.

The province of Quebec comprises that vast stretch of territory lying east of the Ottawa River and north of the United States boundary line, bounded on the north by Hudson Strait, on the west by Hudson Bay, and on the east by Labrador. It is 2000 miles in width from north to south and 1350 miles from east to west, having an area of 706,804 square miles, or almost 25 per cent of that of the United States. The northern section is for the most part uninhabited, but the southwestern portion lying along the lower part of the Ottawa and St. Lawrence Rivers, and extending south to the American border and east to the Saguenay River, is an important and rapidly growing industrial section.

If we superimpose a map of the province of Quebec over a map of the eastern portion of the United States, Quebec will cover the states from the Atlantic Ocean west to Chicago including the Great Lakes, and from North Carolina to Canada, leaving some 200,000 square miles of the northern part of the province overlapping Canada.

The climate of Quebec is quite similar to that of northern New England. The winters are severe, and snow covers the ground from the middle of November to the end of March. The summers are warm and pleasant, and the precipitation, which is fairly evenly distributed over all seasons, averages about forty inches per year.

The Watersheds of the Province

Topographically the country north of the St. Lawrence River is divided into three great watersheds. South of the river and west of the town of Levis, which is opposite the city of Quebec, the country is a low-lying fertile plain; east of the town of Levis the land rises gently to between 1000 and 2000 ft., with elevations of nearly 5000 ft. in the Gaspé Peninsula. On this south side of the river there are no large waterpowers as the watershed is comparatively narrow and, although well watered, is traversed by only a few rivers of any magnitude.

The three great watersheds lying to the north of the St. Lawrence River are the south watershed, draining into the St. Lawrence River; the north watershed, into the James and Hudson Bays; and the east watershed, through Labrador into the Atlantic Ocean. Of these the south watershed, through which flow the tributaries of the St. Lawrence from the Ottawa to the Notashkwan, is the most important. The height of land dividing the north and south watersheds lies some 200 miles north of the St. Lawrence and runs roughly parallel to it. On either side of this height of land there is a vast plateau having a mean elevation of from 1200 to 2000 ft. which begins at the Ottawa with a width of some 150 miles and spreads out like a fan toward Labrador where it attains a width of 500 miles or more. The southern edges of this plateau are for the most part near the St. Lawrence so that the rivers which traverse it make their sharpest descent to sea level not far distant from the main river, and as a consequence much of the water power of this watershed is within easy reach of the industrial section of the province.

The north watershed is drained by many large streams flowing into James Bay, and when the development of the country has progressed far enough to permit their waterpowers to be utilized, enormous amounts of power will become available on the Nottaway, Rupert, East Main, and Kaniapiskau Rivers.

[1] Vice-president and general manager, Shawinigan Water and Power Co.

Presented at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, of The American Society of Mechanical Engineers. Slightly abridged. All papers are subject to revision.

With regard to this northern watershed, although the area is large the precipitation is largely unknown, and the run-off also is largely a matter of speculation.

The east watershed is drained principally by the Hamilton River, on which is situated a water power estimated at 700,000 hp. at Great Falls, some 350 miles from the mouth of the river and 200 miles north of the St. Lawrence River at the west end of Anticosti Island.

The ultimate source of the water power of any country is the precipitation, and the total potential water power produced thereby may be estimated by calculating the potential energy of this precipitation in its descent from the highlands to the sea.

Potential Water Power of the Province of Quebec

To calculate the total potential water power of the province of Quebec we may superimpose a map of the precipitation upon a topographical map of the province and then divide the province into areas having the same average elevation and approximately the same precipitation. An estimate of the potential energy due to precipitation can then easily be made. The precipitation in inches per year at different points of the province is as follows:

Montreal	40	Shawinigan	37.61
Quebec	40.5	Chicoutimi	30
Brome	34.3	Anticosti Island	36
Father Point	33.58		

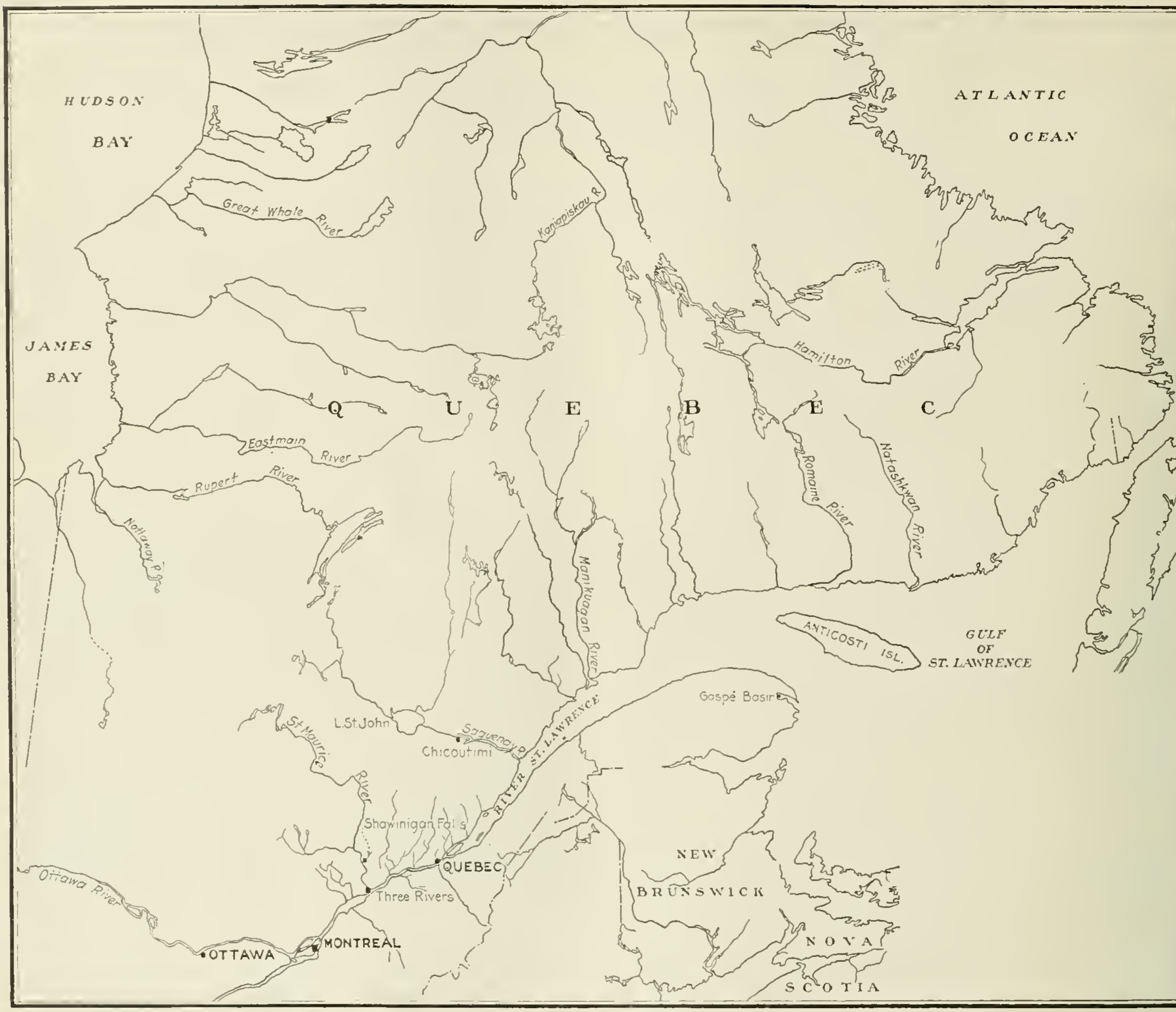
The total area of the province is as stated above roughly 700,000 square miles, of which for the present purpose we may neglect the triangular area cut off by a line drawn from the northern tip of Labrador to the southern end of James Bay containing some 200,000 square miles of snow-covered land, leaving a net area of 500,000 square miles. This area of 500,000 square miles may be divided into four plateaus of different elevations and slightly different rainfall, as follows:

Average precipitation per year in inches	Average elevation in feet	Area in square miles	Equivalent continuous power in kw.
40	1700	170,000	71,400,000
40	1000	220,000	92,400,000
35	500	100,000	18,350,000
40	300	10,000	1,260,000
		500,000	183,410,000

Mr. C. P. Steinmetz, in a paper read before the American Institute of Electrical Engineers in 1918, made a similar computation showing the potential water power from the rainfall in the United States between the thirtieth and fiftieth parallels of latitude and found that over an area of 2,970,000 square miles the potential power was 1000 million kilowatts of continuous power. Prorating the figures obtained above for the province of Quebec, the potential water power of the province due to the precipitation is about 10 per cent higher per square mile of area than the average potential water power of the United States.

It is of course obvious that this amount of power is not available because no water would be left for vegetation, and even were all hydroelectric developments carried out, no allowances have been made for losses due to seepage and evaporation.

If we average the figures for the various stations throughout the province, we arrive at an estimated run-off for the whole province of 18 in. per year. Substituting this figure for the total precipitation, we obtain a total of 88.7 million kilowatts of continuous power, and allowing an efficiency of conversion of 60 per cent from the stream to the distribution center, there remains 53 million kilowatts of continuous power as the maximum possible hydroelectric power which could be produced if during all seasons every drop of water which ran off the 500,000 square miles of territory considered were converted into hydroelectric power. This is of course an impossible condition, as there would be no flowing streams



Map of Quebec Showing Watersheds and Rivers

in the country but only lakes and canals connected together by penstocks discharging through turbines into those of lower levels.

In estimating the amount of power which is actually available we must obviously neglect the energy in the water falling on the upper plateau, which is lost in the first part of its descent from these highlands.

While it is impossible to state accurately the percentage of energy loss before the gathering together of water takes place, it may be conservatively estimated at 50 per cent on an average over the many steep and shallow valleys that go to make up the different drainage basins.

We must also subtract from the total of available energy all the energy consumed by friction of the banks and beds of the rivers and streams, which is sufficient to use up about one-half foot of head per mile on the average; and in addition we must consider as non-available all the energy contained in those portions of the rivers and streams and brooks where the fall is hardly greater than that necessary to produce the required flow of water through the channel. In this class will be included practically all the lower reaches of the main rivers and those tributaries which unite with them below the points of greatest descent.

As continuity of supply is an essential condition to all power service, due allowance must be made for the fact that while the precipitation is more or less equally distributed during the year, the run-off from the precipitation is most unequally divided among the different seasons. During the spring thaw the melting and running away of the accumulated winter snowfall produces flood conditions on all rivers and streams, raising the flow to as much as 20 to 100 times the minimum. The necessary waste of the greater part of the water reduces still further the quantity of energy which may be considered as available for industrial uses, even under ultimate conditions of development.

Combining the sources of lost energy enumerated we may assume that not more than 25 per cent of the 53 millions of kilowatts of energy contained in the total run-off could be converted into electric energy, and therefore that the actual potential energy of the province of Quebec is approximately thirteen to fifteen millions of continuous kilowatts.

In the present state of the art of the development and distribution of hydroelectric power, only those sites near industrial centers and at which water power exists in considerable quantities are capable of being developed. The theoretical available quantity of fifteen to eighteen million kilowatts of continuous power must therefore be very considerably reduced in estimating the quantity of power that is actually adaptable to industrial purposes. From recent surveys of the water powers of the province, and considering only those rivers on which water power is available in such quantities and in such locations as could be economically developed either now or in the near future, the quantity of actually available water power in the province is estimated at approximately 5.25 million kilowatts of continuous power, of which some 800,000 kilowatts have now been developed and utilized. There remains,

therefore, in the Province of Quebec as available commercial water power about 4.5 million kilowatts of continuous power or about 12 million horsepower at 50 per cent load factor.

The Quebec Streams Commission of the Province of Quebec, and the Water Powers Branch of the Department of the Interior at Ottawa, have published during the past several years valuable articles giving detailed information regarding the available water powers, and particularly those which can be developed within the next few years from an economic standpoint.

The Load Factor

The various amounts of power mentioned in this paper thus far have been described as "continuous power," which means that the flow of water producing this power is sufficient to provide the full quantity twenty-four hours a day, three hundred and sixty-five days in the year, and here the author proposes to digress for a moment from the main subject of the paper to discuss briefly the subject of "load factor," or the proportionate duration of use of power.

It must be borne in mind that no industry is able to make continuous use of the power which it requires, and that therefore no power company supplying power for industrial purposes is called upon to supply the total amount of contracted power all day every day in the year. The term "load factor" is used as a measure of the duration of use of power and is defined as average power divided by peak power. The load factors of the various industrial loads in Quebec differ considerably. For instance, paper mills operate a load factor of between 65 and 75 per cent, averaging more nearly 65 per cent; carbide and electrochemical plants operate at 85 to 90 per cent; cement mills at 80 to 90 per cent; and asbestos and mining industries at 45 per cent load factor. The load factor of a hydroelectric station supplying various industrial establishments and providing power and lighting service to communities will obviously be the average of the combined load factors of the various loads. Such a plant will therefore not require to use continuously the flow of its water which will produce maximum output. Provided sufficient water-storage capacity exists, the surplus energy that the normal flow of the river could produce may be stored in the form of water, but otherwise a certain portion of the available energy—which might be very great at certain seasons in the year—must be allowed to run to waste. In estimating the amount of energy available for industrial uses from the flow of the river at a given head, due consideration must therefore always be given to the storage capacity of the watershed and to the amount of regulation of flow which is possible with full utilization of the storage capacity.

TABLE 1 PRINCIPAL WATER-POWER DEVELOPMENTS IN THE PROVINCE OF QUEBEC

River	Location	Company	Available Head, ft.	Total Generating Capacity, hp.
In Operation				
St. Maurice	Shawinigan Falls	Shawinigan Water & Power Co.	150	195,000
	Shawinigan Falls	Northern Aluminum Co.	145	40,000
	Grand Mere	Laurentide Power Co.	84	160,000
St. Lawrence	St. Timothee	Quebec-New England Hydraulic Corpn.	50	21,000
	Cedars Rapids	Montreal Light, Heat & Power Co.	32	229,200
	Soulanges	Montreal Light, Heat & Power Co.	50	15,000
	Lachine Rapids	Montreal Light, Heat & Power Co.	14	13,000
Richelieu	Chambly	Montreal Light, Heat & Power Co.	...	31,000
Ottawa	Hull	Ottawa and Hull Power & Mfg. Co.	40	20,000
		E. B. Eddy Co. (private)	...	10,000
St. Francis	Drummondville	Southern Canada Power Co.	32	6,700
Montmorency	Montmorency Falls	Quebec Ry., Light, Heat & Power Co.	270	5,000
St. Anne	Seven Falls	Laurentian Power Co.	410	20,000
Under Construction				
Saguenay	Lake St. John	Quebec Development Co.	300	400,000[1]
St. Maurice	Gres Falls	Shawinigan Water & Power Co.	65	132,000
Ottawa	Calumet Island	Ottawa and Hull Power & Mfg. Co.	60	60,000

[1] A further 800,000 hp. will be developed later near the mouth of the river.

In plants where no storage capacity exists, the installation of sufficient generating capacity to consume the increased flow of water during the six high-water months becomes economically justifiable by the use of electric steam generators as an adjunct to the plant to make possible the utilization of the excess energy produced during these months by its conversion into steam. The ability to obtain a return from all the energy available at all times of the year will make possible the development of many power sites which, if dependent solely upon the sale of continuous electric power as such, might remain undeveloped.

Early Water-Power Developments

The earliest water-power developments in the province were the old seigniorial mills constructed by the French seigniors to grind the grain of their dependents. These little grist mills were in existence as early as 1650, and were almost always developed by the construction of a small canal which carried the water to an overshot or undershot wheel where the heads used varied from about five or six feet up to ten or fifteen feet.

The first hydroelectric development was the Montmorency plant near the mouth of the Montmorency River, seven miles below Quebec, built in 1895 and having an installed capacity of five 600-kw. generators.

This was followed in 1897 by the St. Narcisse plant on the Batiscan River, with an output of 750 kw. which was transmitted to Three Rivers over a two-phase 12,000-volt transmission line 18 miles long. This was the first high-tension line in the British Empire.

The Chambly plant on the Richelieu River, 17 miles from Montreal, was built in 1898 with four 2000-kva. machines, the output of which was transmitted to Montreal at 25,000 volts, three-phase; and in the same year the Lachine Rapids plant was put into operation with a maximum output of 10,000 kw., at certain times of the year only.

Principal Water Powers Now in Operation

The principal water powers now in operation in the province of Quebec may be divided as follows: Powers on the Ottawa River; powers on the St. Lawrence River, Province of Quebec; powers on the St. Maurice River; powers on the Saguenay River and its tributaries in the vicinity of Chicoutimi; and powers located on the south side of the St. Lawrence River, particularly on the St. Francis River and its tributaries.

The two great developments existing today in this province are located at Cedars Rapids in the St. Lawrence River, thirty miles west of Montreal, and on the St. Maurice River at Shawinigan Falls and Grand Mere. The third great power, which ultimately may eclipse these, is now being constructed on the Saguenay River just below the outlet of Lake St. John.

In addition to the developments enumerated in Table 1, which generate electricity for use in public-utility service or for industrial service in the neighborhood of power developments, there are a large number supplying power for grinding wood. These latter are widely scattered throughout the province, most of them having been built prior to 1910. The total amount of hydraulic power used directly for this purpose in the province has been stated by the Water Power Branch to be 162,825 hp. With the advent of the vertical turbine and the increase in the size of electrical generating units, it became in many cases more economical to develop the power in the form of electricity to be transmitted to pulp and paper mills built in favorable positions rather than to locate the mills at the site of the power development. The amount of hydroelectric power so used is stated to be 157,367 hp., making a total of 320,192 hp. of hydraulic turbines employed in the pulp and paper industry.

Difficulties Encountered in Water-Power Engineering

There are certain difficulties occurring in water-power engineering in this province which meet engineers in every locality where the climatic conditions are similar to those which obtain in its latitude. Ice troubles in the past have caused serious interruptions of service and reductions in the available amount of power. These troubles may be divided into two broad divisions:

a Ice troubles occurring in the power house itself, due to the presence of ice on the racks on the waterwheels

(*Continued on page 429*)

Hydroelectric Developments in Ontario

Present and Projected Developments of Hydroelectric Power in the Province of Ontario, Together With Particulars Regarding the Largest Single Hydroelectric Development in the World, the Queenston-Chippawa Installation

By F. G. GABY,[1] TORONTO, ONT.

THE province of Ontario is richly endowed with water powers, widely distributed over an area of over 400,000 square miles, and its surface waters drain both to the Atlantic and to the Arctic oceans. The water-power possibilities of the streams draining through the Great Lakes system to the Atlantic have been fairly well ascertained, but much remains yet to be known regarding the power possibilities of the streams draining through Hudson Bay into the Arctic. However, preliminary estimates which include Ontario's share in the water powers of her international waters have indicated a total of some 6,000,000 hp., of which about 1,300,000 hp. has already been developed.

The Chief Water Powers of Ontario and Their Strategic Situation

The power potentialities of the Niagara and St. Lawrence Rivers constitute a very large proportion of the available power in the watershed, tributary to Lake Ontario. There are nearly thirty sites, of which about one-half have been developed with an aggregate capacity of 50,000 hp., leaving undeveloped sites with an aggregate capacity of some 15,000 hp. Tributary to Lake Huron are water-power streams with an aggregate potentiality at known sites of nearly 300,000 hp., of which about 100,000 hp. is developed. Tributary to Lake Superior are water-power streams with an aggregate potentiality of about 300,000 continuous hp. About half of this total is on the Nipigon River, on which an initial development has been made for the municipalities of Port Arthur and Fort William by the Hydro-Electric Power Commission of Ontario. The outflow from Lake Superior through St. Mary River constitutes an important water-power site, which has been partially developed. In the extreme west of the province, the English and Winnipeg rivers, which flow into the province of Manitoba, have important water powers; in Ontario these powers aggregate over 250,000 hp.

Fig. 1 Map of Ontario, Showing Watersheds and Rivers

province. Next in importance is the Ottawa River and its tributaries. The power on the main stream, which constitutes part of an interprovincial boundary, is shared by the provinces of Ontario and Quebec. Under conditions of controlled flow, Ontario's share of the power available on the main stream, together with that on the tributaries in Ontario, aggregates about 700,000 hp.

Other important water powers are found in the Trent River watershed... There remain to be mentioned the water powers of the streams flowing from Ontario into James Bay and Hudson Bay. The more important of these streams from the viewpoint of water-power possibilities are the Mattagami, the Abitibi, the Missinaibi and the Albany Rivers. These streams have not yet been adequately appraised; the total water-power possibilities of known sites aggregate upward of 1,000,000 hp.

What, at the present time, however, is of much greater importance to the province of Ontario than its total water-power possibilities, is the fact that in its commercial centers where the greater proportion of the population resides, are situated the largest and most important water powers.

[1] Chief Engineer, Hydro-Electric Power Commission of Ontario. Mem. A.S.M.E.

Presented at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, of The American Society of Mechanical Engineers. Abridged. All papers are subject to revision.

Ontario has no natural supply of coal and has been compelled to import this necessity—both bituminous and anthracite—chiefly from the state of Pennsylvania. The rising cost of this fuel and the fact that manufacturers have been dependent upon outside sources for their supply, have been phases of the power situation in the province which have greatly stimulated, and which doubtless will continue to stimulate, the utilization of the water powers of the province along the lines of hydroelectric development.

Early Hydroelectric Developments in Ontario

The most important *early* hydroelectric development in the province of Ontario from the standpoint of magnitude and extensive transmission, was the plant at DeCew Falls. This plant takes its water from Lake Erie at the level of the upper reach of the Welland Canal at Allenburg. It is a high-head development (265 ft.) of about 50,000 hp. capacity. Current is generated at 2400 volts, 3-phase, 66 cycles, and transmitted at 44,000 volts. The main objective of this DeCew power was the city of Hamilton, in the industrial life of which it has played a most important part.

Niagara Falls. The three large hydroelectric plants at Niagara on the Canadian side of the river have often been described in print, but in view of the subject in hand, it is believed that a brief reference should be made to these developments because of their importance to the general hydroelectric economy of the province of Ontario.

In 1889 negotiations by a group of United States capitalists with the Queen Victoria Niagara Falls Park Commission eventuated in the formation of the Canadian Niagara Power Company—an ally of the Niagara Falls Power Company of Niagara Falls, New York. The water for this plant is drawn from the level of the upper river through an intake canal, and is thence distributed to the intake chambers at the head of each penstock. The penstocks pass vertically down an average depth of about 160 ft. to the turbines. The water finds its outlet to the lower level of the river in the gorge below the falls. The nominal installed capacity of this plant, including a spare unit, is 121,000 hp. The ground was broken for the tunnel on October 4, 1890, and the first commercial power was delivered to the Pittsburgh Reduction Company for the reduction of aluminum ore on August 26, 1895.

The next important development at Niagara was that of the Ontario Power Company, which commenced operation by the delivery of commercial power in 1905. This plant has its intake near the Dufferin Islands, above the falls. The water is conveyed a distance of over 6000 ft. to penstocks by means of underground conduits. The plant operates under an average effective head of about 180 ft. and its present capacity is a little over 160,000 hp. In 1917 the Hydro-Electric Power Commission acquired the whole of the assets, including the generating plant at Niagara Falls, of the Ontario Power Company. This plant is now operated by the Commission.

In 1903 the Electrical Development Company entered into an agreement with the Commissioners of the Queen Victoria Niagara Falls Park whereby the company was to utilize the waters of the Niagara River for the development of 125,000 e.hp. Its plant is situated above the falls and about midway between the headworks at Dufferin Islands of the Ontario Power Co. and of the Canadian Niagara Power Co. The plant operates under a head which varies from 130 to 145 ft., dependent upon river conditions. In 1922 the assets of the company, including the development just described, were acquired by purchase by the municipalities of the Niagara district, and the operation of the plant was placed under the jurisdiction of the Hydro-Electric Power Commission.

There is a demand for the total output of these Niagara plants which represented in their day the highest state of the art to which hydroelectric development had attained. The splendid service given by these installations under the exacting conditions of overload—especially during the period of the great war—reflects great credit upon the engineers and manufacturers responsible for their design and construction.

New Ontario Developments. In the Sudbury, Cockrane, and Cobalt districts of what is known as New Ontario there are several developments on the Metabitchawan, Montreal, Metagami, and Wahnapatie Rivers which aggregate approximately 60,000 hp. and are used for general municipal purposes and the operation of gold, silver, cobalt, copper and nickel mining properties in Northern Ontario. The pulp and mining companies have their own developments to the extent of 125,000 hp. located on the Abitibi, Spanish, Vermillion, Magnetawan and the Onaping Rivers, which they use for their own manufacturing purposes.

Systems and Power Developments of the Hydro-Electric Power Commission

Having now reviewed the outstanding features of hydroelectric development in the province of Ontario, we may next devote attention to some of the more interesting characteristics of the power developments which supply electrical energy to the various systems

TABLE 1 CAPACITY OF PRESENT AND PROJECTED DEVELOPMENTS OF THE HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO

Present Development or Site	Present Plants — Present capacity, hp.	Present Plants — Ultimate capacity, hp.	Projected Developments — Estimated hp.
Niagara System			
Niagara River:			
Ontario Power Co	180,000	150,000	......
Electrical Development Co	125,000	100,000	......
Queenston-Chippawa Development	300,000	550,000	......
Canadian Niagara Power Co. (purchased power)	20,000	20,000	......
Total	625,000	820,000	......
Combined Northern Systems—Severn, Eugenia and Wasdells			
Beaver River:			
Eugenia Falls Development	8,500	8,500	......
Severn River:			
Wasdells Falls development	1,200	1,200	......
Big Chute development	6,200	6,200	......
Port Severn	......	......	1,400
Saugeen River:			
Haywards Falls	......	......	1,020
Port Elgin	......	......	10,000
Kimberley	......	......	1,700
Total	15,900	15,900	14,120
Muskoka System			
Muskoka River:			
South Falls development	1,750	6,000	2,000
Total	1,750	6,000	2,000
St. Lawrence System			
St. Lawrence River:			
Cedars Rapids Power Company (purchased power)	......	......	......
Morrisburg and Long Sault	......	......	600,000
Total			600,000
Rideau System			
Mississippi River:			
High Falls development	3,600	Fully developed	......
Carleton Place development	735	Fully developed	......
Ragged Chutes	......	......	3,600
Total	4,335	......	3,600
Thunder Bay System			
Nipigon River:			
Cameron Falls development	25,000	75,000	......
Alexander Landing	......	......	41,900
Pine Portage	......	......	40,400
Virgin Falls	......	......	30,800
Kaministikwia River:			
Silver Falls (Dog Lake)	......	......	22,000
Total	25,000	75,000	135,100
Ottawa System			
Ottawa River:			
Ottawa and Hull Power & Mfg. Co. (purchased power)	......	20,000	......
Chats Falls	......	......	60,000
Total	......	20,000	60,000
Central Ontario and Trent System			
Developments above Rice Lake	11,140	......	......
Developments below Rice Lake	40,470	......	10,720
Total	51,610		10,720
Nipissing System			
South River:			
Nipissing development	2,500	Fully developed	......
Bingham's Chute	......	......	1,300
Elliotts	......	......	1,150
Gitzlers	......	......	2,160
Cox's Chutes	......	......	1,930
Gimballs	......	......	700
French River: (three developments)			
Chandiere, Five Mile Rapid, and the Dalles	......	......	30,000
Total	2,500		37,240
Grand Total ....1,858,125 hp.			

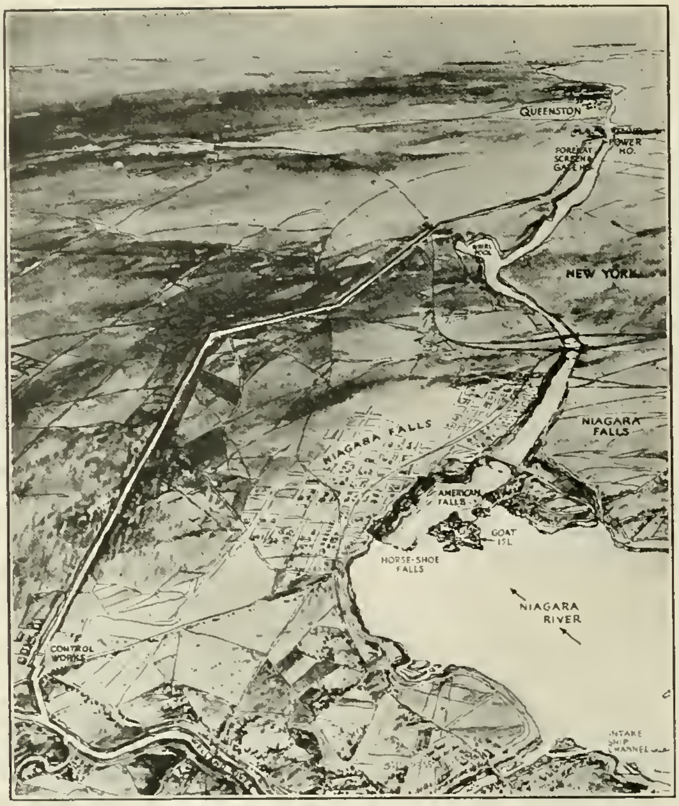


FIG. 2 THE QUEENSTON-CHIPPAWA DEVELOPMENT

of the Hydro-Electric Power Commission to which reference has just been made. In this connection special attention will be directed to certain features of some of the developments installed under the administration of the Commission.

From an initial investment in 1910 of some \$3,750,000 the operations of the Commission have extended until at the present time it administers properties to the value of approximately \$200,000,000 delivering upward of 625,000 hp. to 14 different systems in various parts of Ontario and serving 350-odd municipalities, the systems comprising some 3500 miles of transmission lines.

Transmission Voltages. The frequency employed is 25 cycles in the Niagara system and 60 cycles in all other systems. In the Niagara System the main high-tension lines are operated at 110,000 volts and are carried on steel towers. The secondary distribution from the main transformer stations to the various municipal and distribution stations is chiefly at 13,200 and 26,000 volts, although other voltages are employed. Outside of the Niagara system the only 110,000-volt lines are in the Thunder Bay district where about 70 miles of wood-pole line are operated at this voltage. The main transmission lines of the Severn, Eugenia, Wasdells, and Muskoka systems are operated at 22,000 volts; the St. Lawrence system and the Rideau system lines at 26,400 volts; the Central Ontario and Trent system lines at 44,000 volts—recently raised from 26,400 volts, at which some lines still operate—and the Nipissing system lines at 22,000 volts. Local distribution in the various systems is usually at 2200 and 4000 volts, the service voltages being 110, 220 and 550.

The extent of the hydroelectric developments by the Commission, both actual and conjectural are summarized in Table 1.

Storage. The rapidly increasing demand for electrical energy in all of the fourteen systems operated by the Commission has in some instances already used the available water supply, while in other systems it is only a matter of two or three years or even less, before practically all of the power available under existing conditions of water supply will be requisitioned. The Commission will be able in some cases to increase the supplies available by providing storage. Most of the drainage basins supplying existing developments are well furnished with lakes and reservoir possibilities. The potentiality of the storage available as well as the potentialities of remaining power sites are being investigated by the Commission's engineers, it being recognized that such storage as may economically be developed will be demanded at an early date.

THE QUEENSTON-CHIPPAWA DEVELOPMENT

It is now proposed to describe some of the important features of the largest development in Ontario, in fact, the largest single hydroelectric development in the world, namely the Queenston-Chippawa installation.

The Queenston-Chippawa development, which was placed in service on February 11, 1922, is the latest addition to the Niagara system operated by the Hydro-Electric Power Commission of Ontario. This development will have a normal operating head of 294 ft. to 305 ft. when the installation is complete, which is over 90 per cent of the fall between Lake Erie and Lake Ontario. The conservation of head effected by the reduction of hydraulic losses to a minimum and by refinements in the design of the various essential elements of the project as a whole, has resulted in the production of a power development which is believed to represent the best in modern engineering practice.

The plant when completed will consist of ten 60,000- to 65,000-hp. units running at 187.5 r.p.m. and generating power at 12 kv., three-phase, 25 cycles, which in turn is transformed to 110 kv. for transmission with an ultimate capacity of 575,000 to 650,000 hp.

A glance at Fig. 2 will indicate the relation of the various works comprising the development. Water is taken from the Niagara River about one mile above the falls, is conveyed through the improved section of the Welland River, a distance of $4^1/_2$ miles, thence by a canal $8^1/_2$ miles long to the forebay and screen house located on the Niagara River about one mile south of the village of Queenston. From the screen house, steel penstocks encased in concrete carry the water down the cliff to the power house, from which it passes to the Niagara River.

The Intake. On the Niagara River one of the great obstacles to securing continuity of service is the annual formation and flow of ice. In order to eliminate as far as possible interference of operation due to ice, a special form of intake has been provided.

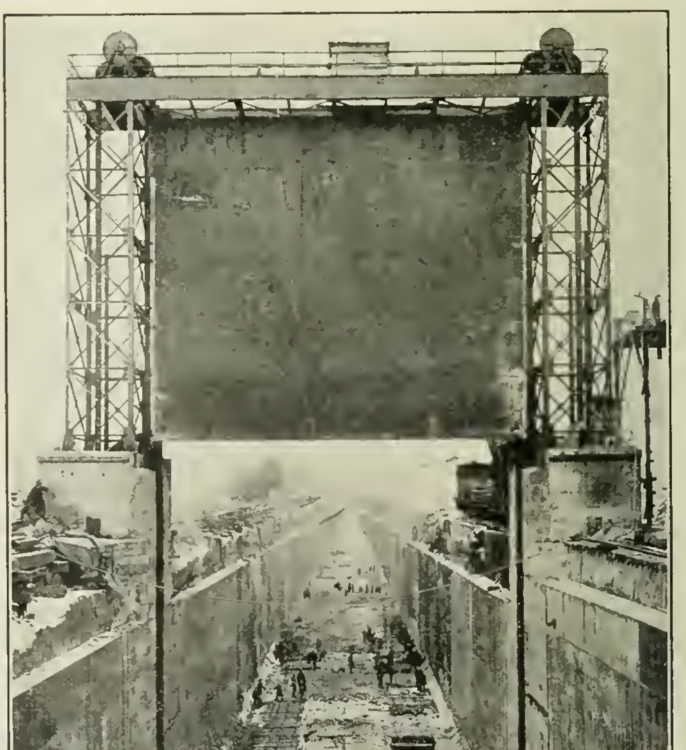


FIG. 3 CONTROL GATE AT UPPER END OF CANAL

The complete structure is approximately 1100 ft. in length and is made up of an entrance with lock gates for navigation, a bulkhead section, and the intake proper, the latter combining two forms of intake; the conventional or surface intake consisting of a concrete barrier or boom with fifteen openings each 18 ft. in width, normally having 8 ft. of submergence, which submergence however, can be

increased, by means of drop gates to any amount up to the full depth of water or 35 ft.; and the submerged intake consisting of gathering tubes or draft distributors, six in number and 675 ft. in length.

Control Gate. Fig. 3 shows the control gate located at the upper end of the canal, where the earth section merges into the rock section. This is the largest single-leaf, roller-type, motor-operated gate ever built. It is motor-operated by means of a worm drive connected to double hoisting gears on the top of the end towers. Roller chains pass over these gears connected at one end to counterweights and at the other to the gate. When raised to its full height it leaves a clearance of 14 ft. above the water level in the canal, which will permit the passage of patrol tugs throughout the length of the waterway.

The total pull on the two chains in raising the gate is 316,000 lb. The chains are made up of pairs of links 9 in. by $1^1/_4$ in. in cross-section, and rollers $4^1/_2$ in. in diameter. The speed of lift is 4.6 ft. per min., thus requiring 12 min. to operate the gate from closed to full open position.

Concrete Lining. Economic considerations prompted the lining of the canal with concrete averaging 20 in. in thickness. The height of the lining was fixed slightly lower than the profile of the water surface existing when the load conditions on the plant are a maximum and the Niagara River flow is a minimum. Thus at all times the lining will be protected by submergence against the action of frost.

Screen House. At the lower end of the forebay, and serving as a dam for the same, is located the screen house. This structure forms the entrance and the control for the penstocks. The entrance to each of the main penstocks is a modified bell mouth consisting of three openings 12 ft. 8 in. wide and 29 ft. high at the rack supports. These three openings gradually converge into one opening 16 ft. in diameter at the point of connection to the penstock. Immediately behind the curtain wall, steel-lined gate checks are provided to support structural-steel gates.

On account of the provision of Johnson valves at the lower end of the penstocks, permanent gates were not installed in the screen house at the entrances to the penstocks. Movable gates have been provided consisting of sectionalized leaves which can be dropped into checks in the piers by means of the 25-ton traveling crane in the screen house. Concrete piers divide the entrances to the penstock into three openings, and the drop gates for closing these openings are made in three sections.

Penstocks. From the screen house the water is carried to the turbines in steel-plate penstocks. The economical diameter for units 1 to 5 was determined to be 15 ft. and in order to simplify the field riveting the lower third of the penstock was made 14 ft. and the upper two-thirds 16 ft. This decrease in the diameter at the lower end permitted the use of plates $1^1/_4$ in. in thickness, which could be readily riveted in the field. The total weight of each penstock is 840,000 lb.

Each penstock ring is made up of two plates with longitudinal joints on the horizontal center line, the plates varying from $^1/_2$ in. at the top section to $1^1/_4$ in. in thickness at the lower section. These joints are all double butt joints, varying from double riveted at the top to quadruple riveted at the lower end. The circumferential joints are also single-butt, double riveted with the butt strap on the outside. The longitudinal joints are calked on the inside, but the circumferential joints are made watertight by electric welding. This type of circumferential joint gives a very much better alignment to the inside of the pipe than can be obtained with the usual outside and inside course with lap joints. In designing the penstocks a stress of 12,000 lb. per sq. in. was used, this figure being taken to provide for the exigencies of corrosion, fatigue,

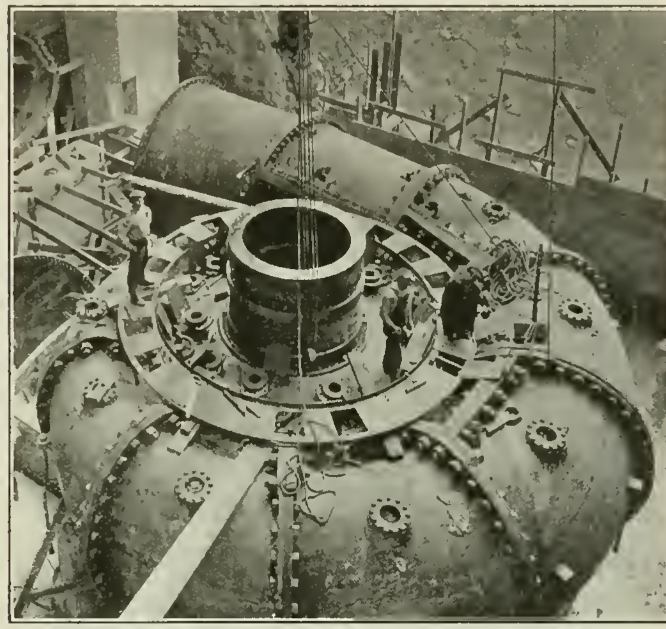


Fig. 5 Turbine Casing Erected in Place

suddenly applied loads, and other indeterminate or unknown contingencies. The internal pressure used for design purposes was taken to be the static head plus the pressure rise due to a complete closing of the turbine gates in $1^1/_2$ sec. This increase in pressure was taken as a maximum at the turbine gates and varying uniformly to zero at the racks.

The penstocks are covered throughout their entire length with a concrete envelope having a minimum thickness of 24 in., which protection will, it is believed, greatly increase the life of the steel pipes.

For discharging ice which may form on the canal and forebay, a chute has been provided at the south end of the screen house leading down the cliff and under the power house to the Niagara River. This ice chute is 10 ft. in diameter, made of reinforced concrete and provided at the upper end with a drop gate.

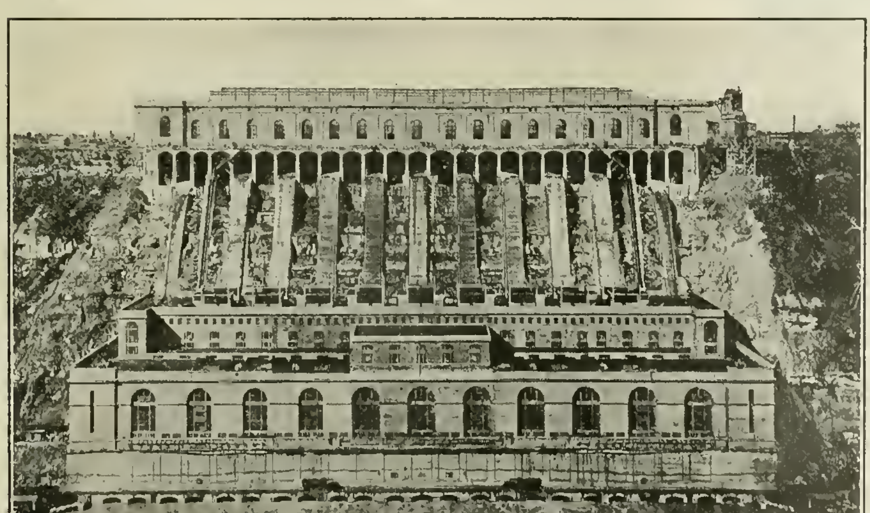


Fig. 4 View of Power House From the River

Generating and Transformer Station. The generating and transformer station (Fig. 4) is located below the escarpment and close to the river's edge. As will be observed, the station extends about one-half the distance to the top of the escarpment. The structure required to house five main units and the service equipment is 350 ft. long, and ultimately this length will be doubled. The substructure is of massive concrete construction carried down to rock foundations, and provides chambers and tunnels for housing and giving access to various kinds of apparatus. The superstructure consists of a structural-steel framework with reinforced-concrete floors and roofs, and concrete, brick, and tile walls and partitions.

Turbines and Governors. Turbines Nos. 1 and 2 are designed for 52,000 hp. and Nos. 3, 4, and 5 for 55,000 hp., all at 305 ft. head, the speed being 187.5 r.p.m. They are of the single-runner vertical

type, set in spiral cast-steel casings. The inlet diameter of the casings is 10 ft. In Nos. 1 and 2, manufactured by the Wellman-Seaver-Morgan Company, of Cleveland, the casings are divided into nine sections with a separate speed ring, while in Nos. 3, 4, and 5, manufactured by the Wm. Cramp & Sons Ship & Engine Building Company, of Philadelphia, the speed ring is cast integral with the casing and the whole divided into 12 sections. The weight of the casing and speed ring in Nos. 1 and 2 is 240,000 lb., while in 3, 4, and 5 it is 180,000 lb.

The runners are made of cast steel in one piece and provided with special renewable seal rings. Those for Nos. 1 and 2 are 125 in. in diameter, and those for Nos. 3, 4, and 5 are 121 in. in diameter.

The gate control is the usual double-regulating-cylinder type operating through rods to a shifting ring connecting to the individual gates through specially designed breaking links.

All parts of the turbines adjacent to rotating elements and to water passages subjected to high velocities are made of special steel and renewable. The main-journal guide bearing on each unit is of the water-lubricated lignum vitae type, such as has been used on all modern vertical-turbine plants. This type of bearing has been selected on account of its simplicity and low maintenance cost.

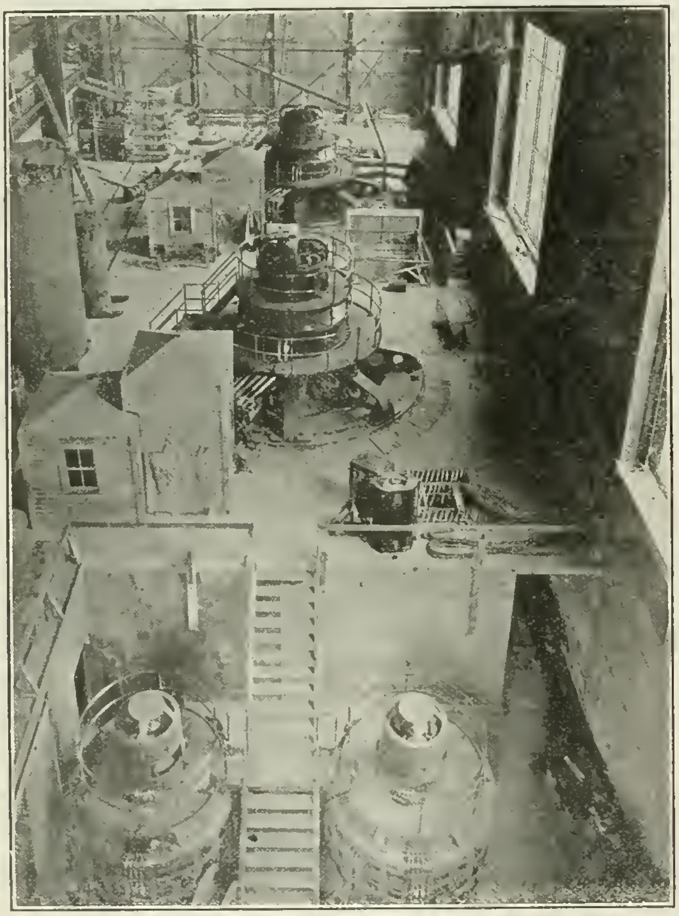


Fig. 6 Interior View of Generator Room

The draft tubes are all of the Moody spreading type except that of No. 1, which is a bent tube.

On account of the limitations in the use of water at Niagara the runners are designed to obtain their maximum efficiency at a point about 10 per cent below their maximum rated output, at which load for the most part they are operated. This condition required that the runners be larger than would normally be used and that the turbines be "gated back." With the gates full open actual tests have shown that the capacity of Nos. 1 and 2 is 60,500 hp. each, and of Nos. 3, 4, and 5, 65,500 hp. each, under 305 ft. head.

Exhaustive tests have been carried out on the units, using the Gibson "pressure-time" method for determining the discharge. The maximum efficiency obtained on each turbine was 93 per cent, exceeding, so far as is known, any figure heretofore recorded on a commercial operating turbine. Fig. 5 shows a turbine casing erected in place.

The governor actuator is set on the generator floor, the flyballs being driven by belt from the turbine shaft. The main valve is located adjacent to the turbine regulating cylinders, 35 ft. below the actuator. To meet the conditions of this layout the pilot valve is hydraulically coupled to a small piston valve which is mechanically connected to the pilot valve of the main dog valve. The hand-control stand is located on the generator floor and operates the regulating cylinders through the governor pressure system.

The governors are operated on the "central" type of pressure system. Two motor-driven centrifugal pumps, each delivering 500 imp. gal. per min., and located adjacent to two 3000-gal. sump tanks built into the concrete substructure of the power house, deliver the governor fluid at a pressure of 200 lb. per sq. in. to a header from which branches are connected to the governors through individual pressure tanks. The capacity of one pump is sufficient to operate five governors.

The fluid used in the governor system is filtered water in which is dissolved, 7 lb. potassium bichromate to every 1000 gal. water. This fluid does not corrode the valve seats and has proved satisfactory in service.

Service Turbines. The two service-turbine casings have a 30-in. inlet diameter and runners of 42 in. outside diameter. The gate mechanism is of the "outside" type, similar to the main turbine.

The governor is the "direct-connected" type, and the pressure liquid is ordinary lubricating oil. The flyballs are mounted upon the main turbine shaft, and the governor stand with self-contained pumping unit is placed on the turbine floor.

A band brake is furnished in order to assist in bringing the unit to a quick stop when necessary.

Johnson Valves. A Johnson valve is located on each penstock near the entrance to the turbine casing. The action of this type of valve has been frequently described in other papers. The control of the Queenston valve is made through the operation of three small Johnson valves which automatically adjust the flow into the central and annular chambers so that the main valve plunger cannot travel at a dangerous rate. The closing stroke is cushioned at the end, and in the opening stroke the plunger moves just sufficiently to permit the wheel case to be primed before completing its stroke. An emergency handle is located on the control stand on the generator floor by which an operator can close the Johnson valve in case of trouble. The valve can be opened only from the control located adjacent to the valve itself.

Acres Control Pedestal. For the purpose of the floor operation of each unit, a pedestal is erected adjacent to each generator. On this pedestal are mounted the pressure and vacuum gages for the turbine, signal light and loud-talking telephone from the control room, temperature indicators from the generator windings, oil- and water-flow indicators, a control for the air brakes, and the emergency closing control for the Johnson valve. An operator standing at the pedestal is in close communication with the control room and at the same time has under his hand the control of the turbine governor and Johnson valve. The signal lights operated from the control room call the floor operator to any unit desired.

Generators. The present five units are each rated at 45,000 kva., 80 per cent power factor, 12,000 volts, three-phase, 25 cycles at 187.5 r.p.m. They are capable of being operated continuously at 49,500 kva. with either voltage or current 10 per cent in excess of the rated values. The type is vertical (see Fig. 6) with direct-connected, shunt-field, commutating-pole, 250-volt, 150-kw. exciter. The overall efficiency of the generating units is slightly in excess of 97 per cent at 80 per cent power factor. The thrust bearing is designed to support a load of one million pounds, which is slightly more than the weight of the rotor plus the hydraulic thrust imposed by the turbine. Upper and lower guide bearings are provided, the latter on account of the length of shaft and to keep the generator a self-contained unit.

The overall diameter of these units is 25 ft., the diameter of rotor over pole faces being 18 ft. approximately. The shafts are 30 in. in diameter in the guide bearings and are provided with a flange at the lower end for bolting to a corresponding one on turbine shaft. The shafts are hollow with an 8-in.-diameter bore and are 30 ft. 3 in. in total length. The overall height of the generators

above the generator floor is 26 ft. 10 in., thus above the main floor only the top of the frame and the upper bracket, thrust-bearing housing, and exciter are visible (Fig. 6).

The weight of the complete generator is 1,400,000 lb. and that of the rotor, 615,000 lb. The largest piece to be handled by the cranes weighs 600,000 lb.

It was specified that there should be a thrust bearing at the top to carry the weight of the rotating part and the total thrust due to turbine at rated speed and at overspeed; that the rotor be capable of operating at an overspeed of 347 r.p.m. without injury to any part; also that provision for easy handling of various parts be made.

Contracts were placed with two manufacturers who used different methods in constructing the generators, the general difference being that one made use of a built-up laminated sheet-steel rotor rim mounted on a small cast-steel spider; of cast iron in the upper and lower bearing brackets; and of a Kingsbury thrust bearing to carry the rotating parts; while the other used a rotor consisting of seven cast-steel wheels shrunk on to the shaft; cast steel in the upper and lower bearing brackets; and a thrust bearing with stationary bearing plate supported on a large number of small springs. Both manufacturers used forged-steel hollow shafts of approximately the same dimensions, which were 30 in. in diameter in the guide bearings and had a forged half-coupling at the lower end.

The steel forgings and steel and iron castings were required to meet the specifications of the American Society for Testing Materials. With reference to the steel castings, particularly those of large section such as are used in the cast-steel rotor wheels, attention is drawn to the advisability of not depending entirely on small test pieces attached to the casting to determine if the annealing has been properly carried out. It is the practice of the Commission on these large rotor castings to require that test pieces taken from 4-in. by 4-in. blocks 12 in. long cast on the outside and underside of the rim meet the specification requirements, also that core-drill samples be taken from the rim at the ends of the arms and if possible from between the arms, these samples being tested and examined to determine the quality of the metal.

The two types of bearings provided are interchangeable in the housings as constructed. In the Kingsbury bearing the shaft is supported on the thrust bearing by a nut threaded on the upper end of the shaft. The nut rests on a thrust collar which rests on the runner plate of the thrust bearing. The runner plate is of cast iron with a very highly finished surface, being true to 0.0002 in.

The stationary bearing surface consists of six babbitted sector-shaped shoes, each mounted on a support on the head of a jack screw so that it is free to tilt.

The maximum diameter of the runner plate is 69 in. The total area of the shoes is approximately 2500 sq. in., so that the unit pressure is 380 lb. per sq. in.

In running, a wedge of oil is dragged between each shoe and the runner plate, the shoe tilting sufficiently to accommodate this wedge, so that the rotor floats on a film of oil.

The friction losses in this bearing at normal load and speed are approximately 90 hp. Lubricating oil is circulated at the rate of about 4 gal. per min. between the purifying system and the bearing housing.

In the spring type of bearing the thrust is taken from the shaft to a cast-steel thrust collar by means of a shear key in a groove in the shaft. The groove is 3 in. wide and the shaft 29 in. in diameter. The thrust collar rests on a runner plate of cast iron 69 in. in diameter and is attached by two 2-in. dowel pins to prevent relative rotation. The carefully finished surface of the runner plate runs on a stationary steel ring with a babbitted surface, which in turn is supported on a nest of over 700 steel spiral springs. The babbitted ring is split in one place radially to give flexibility and the surface is radially grooved to allow oil to reach the rubbing surfaces. The unit pressure is about 265 lb. per sq. in. of bearing surface at 960,000 lb. total downward thrust. Total loss in the bearing is about 125 hp.

Growth in Demand for Hydroelectric Power

The first five units of the Queenston-Chippawa development are now in operation and the other units are being installed as rapidly as possible, and when completed the Commission will have a generating capacity for the Niagara District of over 900,000 hp., including the Toronto Power Co. and the Ontario Power plants.

Since 1910 the demand for "Hydro" service from the Commission has grown from an output of 750 hp., taken by 10 urban municipalities, to one of 628,000 hp. (of which 75,000 hp. is exported) taken by 250 municipalities and 97 townships supplying 335,000 consumers.

Realizing as it does the large amount of time—often several years—that must elapse between the initiation of a new, extensive water-power development and its being brought to the stage where commercial power can be delivered, the Hydro-Electric Power Commission has always been compelled to take early action on behalf of municipalities for the creation of new sources of supply for electrical energy. It has sometimes required a good deal of courage on the part of the officers of the Commission to incur heavy financial outlay years in advance of the actual demonstration of markets to absorb electrical output, but, in no instance, has its judgment eventually been found to have been in error.

At the present time, all evidence points to the fact that by the end of the year 1926 the existing provisions made for the supply of electrical energy to municipalities will be fully taxed and no spare power will be available. The output of the Queenston-Chippawa plant will have been absorbed. The Commission has considered the possibility of producing further power at Niagara Falls, but the chairman of the Commission, Sir Adam Beck, has stated from the public platform that he believes that it would be more profitable for all concerned to turn to the St. Lawrence River for the next large hydroelectric development.

Power on the St. Lawrence River

The province of Ontario shares with the state of New York the water power in the international stretch of the St. Lawrence River extending from Prescott to the international boundary. In this portion of the river there is a possibility of developing upon a conservative basis about 1,600,000 hp., of which 800,000 hp. would belong to Ontario. For several years the Commission has been conducting special surveys and investigations with the view of determining the best means of developing the international reach of the river in the joint interests of power and of navigation.

The International Joint Commission has had the problem of the most efficient development and utilization of the St. Lawrence river in the joint interests of navigation and power referred to it for report. The Commission reported about a year ago to the International Joint Commission in detail on the development of the St. Lawrence, but, so far as is known, the two governments interested—the United States and the Dominion of Canada—have announced no decision respecting the development.

This international stretch of the river is a feature which must be considered in its relationship to the larger project of dealing with the Great Lakes route to the sea. The necessity for additional power in Ontario is urgent; but this can be dealt with at once without making any improvements to the St. Lawrence River for navigation purposes, except in so far as they affect the power works contemplated.

Rates Charged for Electrical Energy

One of the basic principles upon which the Hydro-Electric Power Commission of Ontario operates is the furnishing of electrical energy to consumers *at cost.* Time and again, it has been stated that the rates for light and power resulting from the efforts of the Commission were much less favorable than those prevailing in other places. However, the author wishes to state that nowhere in the world over such extensive areas do communities and citizens obtain electric power and light at such low rates as prevail throughout the hydro municipalities in the province of Ontario, namely, from 1.5 to 3.1 cents per kw-hr. for residence and commercial service, and from $13.26 to $25.14 per hp-year for power service.

The secret of the phenomenal growth of the operations of the Commission lies in the fact that as the trustee and agent of coöperating municipalities it has made available to them electrical energy *at cost,* which they have then distributed and vended to their individual consumers at *as near cost as possible.* Moreover the Commission has made its distribution of energy to small municipalities and to rural districts, and the demand of these small municipalities aggregates a substantial load. Electrical energy, once a luxury, has now become a common commodity of the people.

Discussion on Papers on Hydroelectric Powers in Canada

THE preceding papers, Power Development in the Province of Quebec, by Julian C. Smith, and Development of Hydroelectric Power in Ontario, by Frederick A. Gaby, were presented at the first power session of the Spring Meeting, held on Tuesday morning, May 29. Prof. A. G. Christie was presiding officer. Mr. Smith's paper was presented by P. S. Gregory, one of his associates.

F. Darlington,[1] who opened the discussion on these papers, gave emphasis to a statement by Mr. Gaby, pointing out that economic operations were rapidly extending the application of power and that it was most important that the supply should keep pace with the need. He referred to certain features of the power industry that were international in their scope, such as the increased centralization and unification of power service by interconnecting and expanding existing electric systems. This he characterized as the greatest forward step that could be taken to put cheap and dependable power within reach of all. He stated that it was not enough to have a huge power plant at Niagara Falls or on the St. Lawrence or in the Pennsylvania coal fields, for while power confined to these places might be used in factories or electrochemical works located at the source, its more general use and broader application must be through wide distribution to industrial and social needs. Only by wide distribution from the best natural power resources, could the public be properly served.

Of the two basic resources for power generation—fuel and water—one was conserved by saving it, the other was lost if it was not used; but where both were available the best conservation was achieved by using them to supplement each other. Then also, whichever source of power was used there must be great generating plants and power-transmission systems, and conservation required that the fullest possible use should be made of these structures.

All the conditions for conservation and high economy were enhanced by interconnections between electric systems to combine the loads into big blocks and permit the use at all times of the most economical available source of power; and when new generating plants were built always the most efficient source of power within the area of the interconnected system could be used, whether it was a water power or a steam plant at a coal mine, or at tidewater or elsewhere.

In this connection Mr. Darlington called to mind the idea sometimes erroneously held, that if any given electric company had the cheapest source of power within practical transmission distance, such a company would have little or nothing to gain by tying in with other less fortunately situated concerns. This, he said, was radically wrong, even from a purely selfish point of view, for the more economical a generating plant might be, the more important it was that the fullest possible use should be made of it, and interconnection in great superpower systems brought opportunities for the fullest use of the most efficient plants, with corresponding economy and conservation. For example, a superior coal-mine plant, say in Pennsylvania, would gain much by interconnection with a New England, New York, or New Jersey superpower system, or still more by interconnection with the St. Lawrence, for by such means it would secure a fuller use of its plant, and a relay or breakdown connection for use in case of emergency.

Mr. Darlington referred to a statement made by Mr. Smith that the powers of Quebec would be fully utilized in 29 years, urging conservation through the best utilization of both water power and steam power by coördination and interconnection with United States resources.

John R. Freeman,[2] paid a tribute to the foresight of the Canadian Water Power Branch in studying the water-power resources long in advance of demand and seeing that each was developed to the best of its possibilities. They had mapped everything out before it had any real commercial value and had surveys on record so that when there was development there should be no tendency to make use of the best and leave the rest. The work of the Water Power Branch of the Dominion Government, he said, was model for the whole world, and there had been little appreciation of the magnificent work that it had been doing for twenty years not only in surveying water-power sites but also in the actual building of storage reservoirs.

Mr. Freeman referred to his early days in water-power work, fifty years ago, when he was with the water-power company at Lawrence, Mass. At that time there were about seventy turbines in Lawrence for a total of about 15,000 hp., and it used to be said that the Merrimac River was the hardest-worked river in the world. Now a single one of the Chippawa turbines had a greater capacity than all those seventy turbines at Lawrence plus all the turbines then at Lowell and Manchester.

W. M. White,[3] thought the hydroelectric achievements in Ontario and Quebec as described by the speakers were a striking illustration of what the engineer could do in developing nature's resources. The reason why the American manufacturer could compete successfully in the markets of the world and yet pay higher wages than his foreign competitors was because each American workman had behind him more horsepower per man than his competitor's workman had. Since the cost varied directly as the amount of power expended in production, it naturally followed, by inevitable law of competition, that the workman who could direct the greatest amount of power would receive the greatest wage. He urged on the engineers that they recommend the development of power in any form.

Mr. Gregory[4] took up the question of interconnection of plants, interpreting Mr. Smith's statement that the electric steam generator was a necessary adjunct to all hydroelectric plants. This statement did not refer to a steam stand-by plant in connection with the hydro. It was not the custom, he said, to have steam stand-by plants, but as in all rivers in Canada the flow varied very greatly in different seasons, there were times in the year when water must be spilled over the dam, and it was in order to utilize this water that electric steam generators were being used and had been pushed to a high state of development. He mentioned as examples two electric steam generators in the plant of the Laurentide Company at Grand Mere which, united, had a capacity of 2500 kw., or 2500 steam b.hp., and also to a steam generator in the mill at Shawinigan having a capacity of about 3000 kw. or 3000 b.hp. The power that was used in these steam generator was surplus power which would otherwise spill over the dam. The interconnection which was made use of in Canada was interconnection of water-power plants on different rivers, on different watersheds where the periods of high water varied. For instance, if the plants which were now developed or would be developed on the Saguenay River could be connected with the plants developed on the St. Lawrence, there would result a far shorter period of low water because the high-water period on the Saguenay was from three weeks to a month or more behind the high-water period on the St. Lawrence. This would also apply to plants farther west which had their high-water period earlier than those on the St. Lawrence.

Mr. Gaby commented on Mr. Darlington's statement in regard to interconnection, mentioning illustrations of interconnection in the Ontario systems.

Mr. Freeman inquired as to the difference between steam-generated electricity and electricity generated by coal, that is, assuming coal to be worth an ordinary price of $8 or $10 a ton what did the companies get for their water power per year when they put it into steam boiler horsepower ?

Mr. Gregory, in reply, said that one kilowatt-hour of electrical energy would produce about 3 lb. of steam at ordinary pressure, say 125 lb. per sq. in. There were 3412 B.t.u. in a kilowatt-hour. Taking the average of evaporation of $7^1/_2$ lb. of steam per pound of coal, which was a reasonable average, one ton of coal would produce 15,000 lb. of steam; therefore 5000 kw-hr. was the equivalent of one ton of coal, and if a ton of coal cost $10, the 5000 kw-hr. would be worth two mills each. There were 6500 kw-hr. in one horsepower-year at 100 per cent load factor. At two mills each they would be worth $13 per horsepower-year, and so on in that regular ratio.

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[2] Pres., Mfrs. Mut. Fire Ins. Co., 815 Grosvenor Bldg., Providence, R. I. Past-President A.S.M.E.

[3] Mgr., Ch. Engr. Hyd. Dept., Allis-Chalmers Mfg. Co., Milwaukee, Wis. Mem. A.S.M.E.

[4] Assistant to Vice-President, Shawinigan Water Power Co., Montreal, Canada.

Effect of Feedwater Heating on Plant Economy

Studies of a Plant Equipped with 30,000-Kw. Units Which Clearly Indicate the Advantage of Bleeding the Main Turbine Both in Plants With and Without Economizers

By G. G. Bell,[1] Pittsburgh, Pa.

The effect of feedwater heating on plant economy is very interestingly discussed in a paper presented by Linn Helander[2] at the A.S.M.E. Annual Meeting, December, 1922. Mr. Helander has made a very complete study of the subject, and shows the theoretical relation between plants equipped with large and small house turbines, both with high boilers without economizers and medium-sized boilers with economizers.

In the spring of 1922 two more 30,000-kw. units were purchased for the Windsor station of the West Penn Power Co., Pittsburgh, Pa., the boiler-drum pressure was raised from 250 to 350 lb., and on account of this higher pressure steel-tube economizers were substituted for the cast-iron economizer which had been installed with the first 16 boilers in the plant.

The troubles which other plants had had with corrosion in steel-tube economizers necessitated the installation of deaërating apparatus. Manufacturers of deaërating apparatus claimed that air separation was easier at temperatures above 160 deg. fahr. Experience with a closed system of feedwater heating which prevented enrichment had maintained an average oxygen content in the feedwater above 0.25 cc. per liter, provided the feedwater temperature was maintained around 210 deg. fahr. Investigations of an existing plant equipped with economizers had indicated some advantages in increasing the feedwater temperature to 210 deg. fahr. by utilizing the exhaust steam from a house turbine of sufficient size

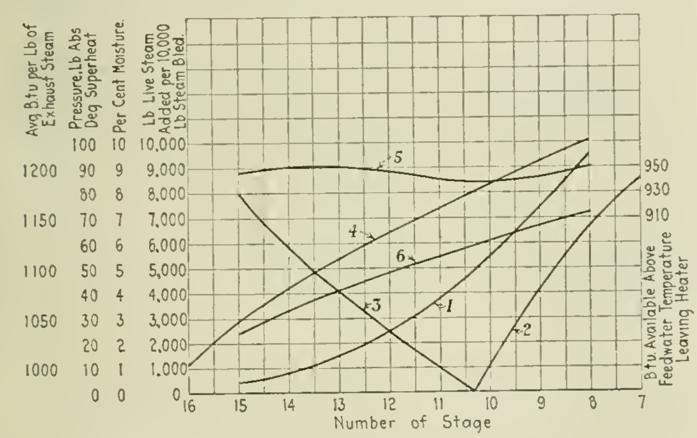

Fig. 1 Data on Steam Extracted from 30,000-kw. G. E. Curtis Turbine

(Steam condition, 300 lb., 200 deg., and 1 in. back pressure; load on turbine, 28,000 kw.
Curve 1—Absolute pressure at various stages
Curve 2—Deg. superheat in steam bled from the various stages
Curve 3—Percentage of moisture in bled steam
Curve 4—Average B.t.u. per lb. of bled steam
Curve 5—B.t.u. available for heating feedwater to maximum possible temperature by steam bled from any stage
Curve 6—No. of lb. of live steam that must be added to permit extraction of 10,000 lb. of steam at various bleeding points.)

to supply the auxiliaries with power; although subsequent investigations have demonstrated that probably there would be a slightly higher saving if the study had been made for a temperature of 190 deg. instead of 210 deg.

In the new addition it was decided to heat the condensate by steam bled from the main unit instead of exhaust steam from the house turbine, and it was thought that the best temperature at which the feedwater should enter the economizers should not be less than 210 deg. on account of the more efficient use of the steam in the main unit. To check this a study was made, as a result of which it was decided to heat the feedwater to the highest temperature possible by extracting steam from the thirteenth stage.

Upon the preparation of Mr. Helander's paper, these studies were revised. Additional data on the turbine were obtained so as to give complete information for bleeding all stages from the eighth to the fifteenth, inclusive, and the effect on the economy of the station of single-, double-, and triple-stage bleeding within these limits was studied.

Data on steam extracted from the 30,000-kw. G. E. Curtis turbine at a load of 28,000-kw., steam conditions at throttle 300 lb., 200 deg., and 1 in. back pressure, are shown in Fig. 1.

In determining the temperature to which the feedwater could be heated by each of the various stages, it was assumed that there was

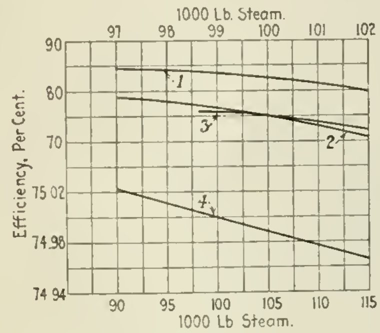

Fig. 2

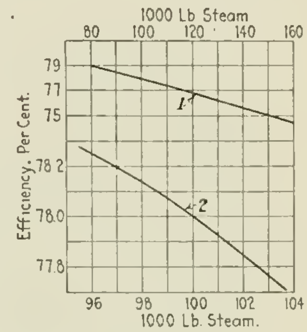

Fig. 3

Fig. 2 Efficiency of 14-High Cross-Drum B. & W. Boiler

(8341 sq. ft. of steel-tube economizer; steam pressure at drum, 325 lb.; temperature at superheater outlet, 225 deg. fahr.; feedwater temperature, 210 deg. fahr.)

Fig. 3 Efficiency of 20-High Cross-Drum B. & W. Boiler

(No economizer; steam pressure at drum, 325 lb.; temperature at superheater outlet, 225 deg.; feedwater temperature 210 deg.)

a loss between the turbine and the heater of 1 lb. when steam was extracted from the fifteenth stage, of $1^1/_2$ lb. when extracted from the fourteenth stage, and 2 lb. when extracted from the thirteenth or any higher stage; and that in all cases the maximum temperature to which the feedwater could be heated was 10 deg. lower than the temperature corresponding to the pressure of the steam at the heater.

The boilers purchased for Windsor are Babcock & Wilcox cross-drum boilers 14 tubes high and 42 tubes wide, and are equipped with a slag screen and Babcock & Wilcox inclined baffle. The front headers are set 21 ft. above the floor, the drum center being 35 ft. 3 in. Four boilers are provided per unit, although it was assumed that when the turbine was operating at its point of best efficiency, which is 28,000 kw., three boilers would supply steam for the unit, the output of each boiler being about 100,000 lb. when feedwater is supplied at a temperature of 210 deg.

The extra boiler capacity would be utilized in reducing the rating on the boilers in the older section of the plant, which are not as efficient or as liberally stokered as the newer boilers.

Fig. 2 shows the efficiency of the new boiler and steel-tube economizer at various ratings. Curve 1 shows the combined efficiency of boiler and economizer; curve 2 the efficiency of the boiler alone, and curve 3 the boiler efficiency corrected for the effect of change in capacity on the efficiency of the economizer. Curve 4 is that portion of curve 3 which is used, amplified so as to permit of reading any slight variation in the relative efficiency of the boiler when operating at slight differences in output.

These figures are based upon 12 per cent CO_2. It is necessary in order to compare the results of bleeding from various stages to work to a fraction of one per cent. All computations were checked by the comptometer.

Fig. 3 presents similar data for a 20-tube-high boiler without economizers. Curve 1 gives the efficiency of the boiler at various ratings, while curve 2 is that portion of curve 1 which is used, amplified so as to permit of reading any slight variation in the relative

[1] West Penn Power Co., Pittsburgh, Pa.

[2] Feed Heating for High Thermal Efficiency, by Linn Helander, Trans. A.S.M.E., vol. 44; also (abridged) Mechanical Engineering, February, 1923, p. 105.

efficiency of the boiler when operating at slight differences in output.

In connection with the 14-tube-high boiler, 8341-sq.-ft. steel economizers are installed. Table 1 gives the rise in the economizers when operating at a constant output of 100,000 lb. of steam per hour with feedwater temperatures of 135, 170, 210, and 250 deg.

TABLE 1 TEMPERATURE RISE IN ECONOMIZERS WHEN OPERATING AT A CONSTANT OUTPUT OF 100,000 LB. OF STEAM PER HOUR WITH VARIOUS FEEDWATER TEMPERATURES

	Feedwater temperatures, deg. fahr.			
	135	170	210	250
Gas temperature entering economizers, deg. fahr.	595	595	595	595
Gas temperature out of economizers, deg. fahr	297	319	345	370
Drop in economizers, deg. fahr.	298	276	250	225
Average gas temperature, deg. fahr.	446	457	470	482.5
Water inlet to economizers, deg. fahr.	135	170	210	250
Estimated rise in economizers, deg. fahr.	128	118	107	96
Temperature of water leaving economizers, deg. fahr.	263	288	317	346
Average water temperature, deg. fahr	199	229	263.5	298
Average thermal difference in economizers, deg. fahr.	247	228	206.5	184.5
Rise in economizers, deg. fahr.	128	118.4	107	95.8

The figures are derived from guarantees based on 210-deg. feedwater and are proportional to the arithmetical mean of the temperature differences.

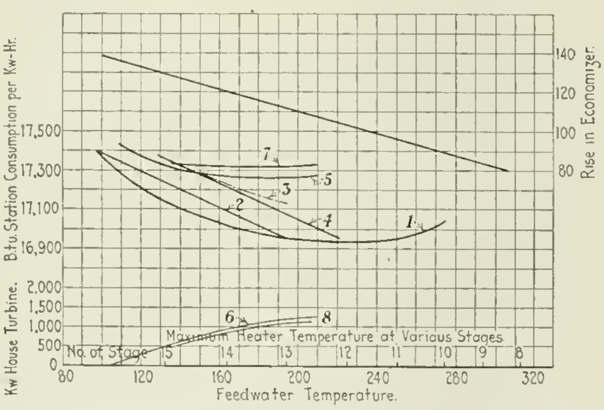

Fig. 4 Comparison of Effect on Station Economy of Heating Feedwater by Exhaust Steam from House Turbine, Efficient Duplex-Driven Auxiliaries and Single-Stage-Extraction Heating

(North extension of Windsor power station. 30,000-kw. G. E. turbines, 28,000-kw. load; 14-high cross-drum B. & W. boilers; induced draft; 60 per cent economizer; steam conditions at throttle, 300 lb., 200 deg., 1 in. back pressure.)

These results are plotted in Fig. 4, which also shows a comparison of single-extraction heating and heating the condensate by exhaust steam from a house turbine if the Windsor plant is equipped with a 14-tube-high boiler and 8341-sq.-ft. economizers.

Curve 1 shows the heat consumption of the plant if the turbine is arranged for single-stage bleeding. These results are arrived at by calculating the heat requirements with bleeding at various stages from the tenth to the fifteenth, and drawing a curve through the points thus obtained. The curve represents the results which might be obtained if the turbine were designed with an infinite number of stages and could be bled at any one of them. As a matter of practice these results can only be obtained when steam is bled from any one of the six stages coming within the limit of this curve and the feedwater is heated as hot as possible by the steam extracted from the turbine.

Curve 2 shows the effect of bleeding from the thirteenth stage and throttling the amount of steam bled so as to get a varying temperature. This is practically a straight line. For the purpose of this study the condensate was assumed to be heated first approximately 20 deg. by the heat contained in the steam escaping from the steam seal. Twenty degrees is also the amount the condensate would be heated if before passing into the first bleeder heater it first cooled the generator air and then absorbed the heat in the bearing and transformer oil for the unit.

On curves 1 and 2 it was assumed that the boiler-feed pump was motor-driven. If in place of a motor-driven boiler-feed pump a steam-driven pump is used, curve 3 will represent the heat requirements of the station. When sufficient steam is bled from the main unit to heat the feedwater to the maximum obtainable from the thirteenth stage, the heat consumption in the plant equipped with a motor-driven pump is approximately 1 per cent less than in one provided with a steam-turbine-driven pump. This is when the exhaust steam from the steam-driven boiler-feed pump is discharged into the same heater as the steam bled from the main unit. When using a steam-driven boiler-feed pump the minimum temperature increased from 97.5 to 127.5 deg. fahr.

Curve 4 shows the results if steam from the boiler-feed pump is discharged to a separate heater and used to heat the feedwater sufficiently above the temperature of the feedwater leaving the extraction heater to get the necessary reëvaporation to permit the deaërator to function satisfactorily. Where the pressure will permit, the exhaust steam from the turbine glands is discharged into the same condenser as the exhaust steam from the boiler-feed pump. The curve indicates that approximately the same results can be obtained by using the turbine-driven pump as with the motor-driven pump, provided that separate heaters are used and the feedwater is heated approximately 25 deg. above that used with a motor-driven-boiler-feed pump.

Curve 5 shows the results which would be obtained if the feedwater were heated by exhaust steam from a house turbine. Guarantees were obtained on house turbines designed for three different back pressures, and in figuring this curve the steam consumption used in each case would apply only if a special house turbine were designed for the operating conditions under consideration. This curve indicates that there is very little difference in the economy of using a house turbine in connection with the 14-tube-high boiler and 60 per cent economizer with feedwater temperatures between 170 and 190 deg. Assuming that this house turbine had been bought for a back pressure corresponding to 180 deg., if the feedwater temperature were then varied by increasing or decreasing the output from the house turbine, the heat requirements of the plant over the range would be higher than shown in curve 5, and would only coincide with that curve when using a feedwater temperature of 180 deg., the point for which this particular turbine was designed.

Curve 6 shows the amount of power which can be obtained from the house turbines when heating the feedwater to the temperatures shown in curve 5.

Curve 7 shows the results which would be obtained if the feedwater were heated by exhaust steam from efficient high-speed geared turbines driving the auxiliaries. In this case one design of turbine is used and operated with various back pressures, so that full advantage is not taken of the increase in vacuum which it is possible to get with the lower feedwater temperature. The water rate for various feedwater temperatures is given in Table 2.

TABLE 2 WATER RATE FOR VARIOUS FEEDWATER TEMPERATURES

Final feedwater temperature, deg. fahr.	Back pressure on turbine exhaust, lb. per sq. in.	Water rate, lb. per brake hp-hr.
135	4.53	16.5
170	7.99	17.0
210	16.13	21.0

The curve indicates that within the range of the temperatures under consideration there is practically no difference in the heat requirements of the plant, although if the small geared sets were so designed as to show an increase in economy with a decrease in back pressure, it would pay to lower the feedwater temperature to the lowest point that was practicable and still prevent the sweating of the economizer tubes.

Curve 8 shows the amount of power generated by the geared-turbine-driven sets. The reason that curves 5 and 7 approach each other at the lower temperatures is that the house turbine is of larger capacity and at low feedwater temperatures is operated at part loads, whereas in curve 7 it is assumed that only enough of the gear-driven units are run to give the required temperature when each turbine is carrying the maximum load.

Fig. 5 shows a comparison of results on the Windsor plant if the turbine were arranged for single-, double-, or triple-stage extraction heating and the plant equipped with 14-tube-high boilers and 8341-sq.-ft. economizers.

Curve 1 shows the heat consumption of a plant arranged for single-stage bleeding at any of the temperatures within the limits of the curve. This curve is the same as curve 1 of Fig. 4 and shows best results at a feedwater temperature of 225 deg. fahr., with a very slight increase in heat requirements by increasing or decreasing the feedwater temperature 25 or 30 deg.

Curve 2 shows the heat consumption of a plant arranged for bleeding from the fourteenth and a higher stage.

Curve 3 shows the heat consumption when bleeding from the thirteenth stage and a higher stage.

Curve 2 shows that minimum heat requirements are obtained by a combination of the fourteenth and twelfth or eleventh stages at a temperature of 225 or 251 deg. fahr.

Curve 4 shows that the best results with triple-stage heating are obtained with a combination of the fourteenth, twelfth, and tenth stages, the best results being obtained at a temperature of 275 deg. fahr.

Curve 5 shows the heat consumption with triple-stage heating using the fourteenth, eleventh, and a higher stage. This combination is not as efficient as that shown in curve 4.

These studies are all made for a plant operated with a motor-driven boiler-feed pump. They indicate that there is very little difference between bleeding the eleventh, twelfth, or the thirteenth stage with single-stage heating; and that for double-stage heating a combination of the fourteenth and twelfth or eleventh stages gives the best result, the heat requirements per net kw-hr. being about 16,750 as against 16,940 B.t.u. for single-stage heating. In triple-stage heating a combination of the fourteenth, twelfth, and tenth stages gives the best results, the heat requirements for triple-stage bleeding being about 16,600 B.t.u. as compared with 16,750 B.t.u. for the double-stage heating and 16,940 B.t.u. for single-stage heating.

While there are a number of points to consider in obtaining plant requirements, the work can be reduced to a comparatively simple form; and with a set of curves such as those in Fig. 1 which give information for various stages and temperatures, etc., a point can be determined every twenty minutes by using a slide rule. However, a slide rule is not accurate enough to give smooth curves.

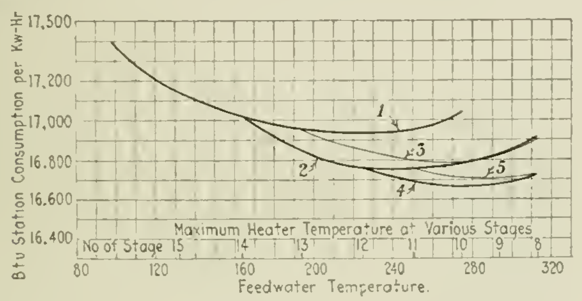

Fig. 5 Effect of Single-, Double-, and Triple-Stage Extraction Heating on Feedwater Temperature and Station Economy

(North extension of Windsor power station. 30,000-kw. G. E. turbines, 28,000-kw load; Steam conditions at throttle: 300 lb., 200 deg., and 1 in. back pressure. 14-high cross-drum B. & W. boiler; 60 per cent economizer; induced draft.)

In order to illustrate the method used in making these computations the formulas employed are given below, the following notation being adopted.

- A = pounds of steam required by main turbine to produce 28,000 kw. per hour when no steam is extracted from turbine
- X = thousands of pounds of steam bled from main unit to heat the feedwater in the first-stage heater
- Y = thousands of pounds of steam bled from main unit to heat the feedwater in the second-stage heater
- Z = thousands of pounds of steam bled from main unit to heat the feedwater in the third-stage heater
- r_x = pounds of steam which have to be added per thousand pounds extracted from the x-stage
- T_c = temperature in deg. fahr. of condensate leaving main condenser
- T_x = temperature of condensate leaving a heater supplied with steam from the x-stage
- B = pounds of steam entering condenser
- C = B.t.u. by test in the amount of steam required for sealing the high-pressure gland of main unit. This is a constant and is 5,500,000 B.t.u. above the liquid temperature of 78 deg. Where it is desired to use the number of B.t.u. in the gland steam above 32 deg., a figure of 5,700,000 is used
- D = total pounds of live steam to be supplied to turbine
- E = net kw-hr. put out by plant
- H_x = average total heat in steam bled from main unit at the x-stage
- F = equivalent pounds of steam that each boiler would evaporate if supplied with feedwater entering the 20-high boiler (or the economizer in case boiler is equipped with economizer) at 210 deg. fahr.
- H_s = total heat in steam leaving superheater
- h_x = heat in the condensate above 32 deg. after being heated by the steam bled from the main turbine at the x-stage
- R = rise in economizer after condensate has been heated by steam extracted from the one or more stages of the main unit
- R_{210} = rise in economizer when condensate enters economizer at a temperature of 210 deg.
- B_e = boiler efficiency
- P_e = ratio between results which we expect to get in ordinary operation as compared with the results which might be expected from manufacturer's guarantees. This ratio includes the plant losses from condensation, steam leaks, soot-blower loss, radiation from steam pipes, etc.
- G = total steam output of boilers in operation supplying each unit. In this study each boiler was assumed to have an efficiency of 75 per cent when the boiler and economizer together were supplying 100,000 lb. of steam per hour or 78 per cent when steam was supplied by a 20-high boiler operating at the same output.

Total live steam to turbine $= A + Xr_x + Yr_y + Zr_z$

Amount of steam to be bled by first-stage heater:

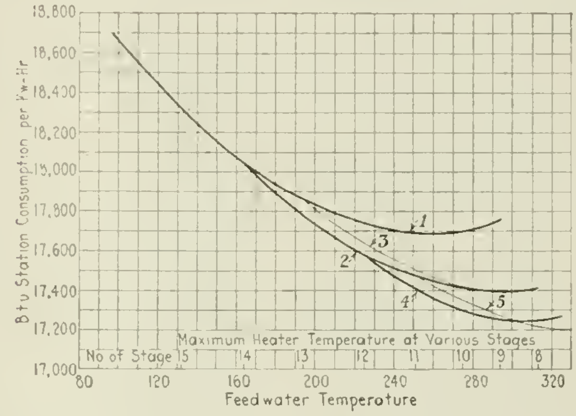

Fig. 6 Effect of Single-, Double-, and Triple-Stage Extraction Heating on Feedwater Temperature and Station Economy

(North extention of Windsor power station. 30,000-kw. G. E. turbines, 28,000-kw. load. Steam conditions at throttle: 300 lb., 200 deg., and 1 in. back pressure. 20-high cross-drum B. & W. boilers; no economizer; natural draft.)

$$X = \frac{(A - X - Y - Z + Xr_x + Yr_y + Zr_z)(T_x - T_c) - C}{H_x - h_x}$$

Amount of steam to be bled by second-stage heater:

$$Y = \frac{(A - Y - Z + Xr_x + Yr_y + Zr_z)(T_y - T_x)}{H_y - h_y}$$

Amount of steam to be bled by third-stage heater:

$$Z = \frac{(A - Z + Xr_x + Yr_y + Zr_z)(T_z - T_y)}{H_z - h_z}$$

To find the relation between X and Y, by changing the form of the equations we get

$$\frac{X(H_x - h_x) + C}{T_x - T_c} = A - X - Y - Z + Xr_x + Yr_y + Zr_z$$

$$\frac{Y(H_y - h_y)}{T_y - T_x} = A - Y - Z + Xr_x + Yr_p + Zr_z$$

Subtracting,

$$Y = \left[X + \frac{X(H_x - h_x) + C}{T_x - T_c}\right]\left(\frac{T_y - T_x}{H_y - h_y}\right)$$

All the quantities in the above equation are known except X and Y, so that a definite relation can be established between them.

Similarly, by combining the expressions for Y and Z the relation between them will be found to be

$$Z = Y\left[1 + \frac{H_y - h_y}{T_y - T_x}\right]\frac{T_z - T_y}{H_z - h_z}$$

Substituting the known values for a combination of the fourteenth, eleventh, and eighth stages we find that these equations when solved give simple answers.

$$Z = 0.771Y$$
$$Y = 1.110X + 5915$$
$$Z = 0.771Y = 855X + 4550$$

Substituting these values of Y and Z in the equation for X permits us to find X, and as the relations of X to Y and Z are known

we can then readily find the amount of steam bled at each stage; and multiplying this by the ratio of the amount of live steam that has to be added per 1000 lb. bled we can find readily the total steam supplied to the turbine, as follows:

$$D = A + Xr_x + Yr_y + Zr_z$$

The steam passing to the condenser is

$$B = (D - X - Y - Z)$$

There are two variables in considering the boiler rating; one is the number of pounds of steam to be evaporated, and the other is the number of B.t.u. to be added, which varies on account of varying feedwater temperature. When the economizer was supplied with 210-deg. feedwater each of the three 14-high boilers and economizers was assumed to be producing 100,000 lb. of steam or a total of 300,000 lb., the efficiency of the boilers alone was taken as 75 per cent (see Fig. 2), and the boiler efficiency under all other conditions was determined from this by correcting for changes in efficiency due to changed output and taking into account the effect of variation in feed temperature.

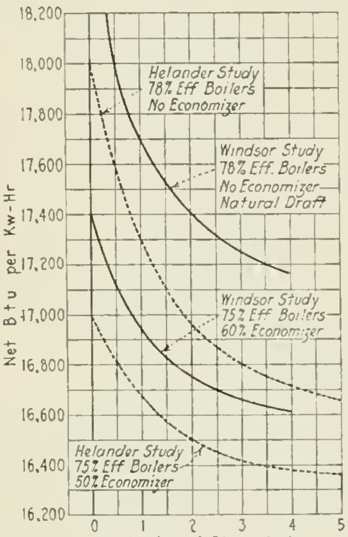

FIG. 7 COMPARISON OF WINDSOR AND HELANDER STUDIES OF EFFECT OF VARIOUS-STAGE BLEEDING ON POWER-STATION ECONOMY

If F = output of each boiler in pounds of steam per hour referred to 210-deg. feed temperature as a basis,

$$F = 100{,}000 \times \frac{H_z - h_z - R_z}{H_{210} - h_{210} - R_{210}} \times \frac{D}{300{,}000}$$

Fig. 2 gives the efficiency of the 14-tube-high boiler.

The net B.t.u. per kw-hr. output of the plant is obtained from the formula:

$$D \times \frac{H_z - h_z - R_z}{E} \times \frac{1}{B_e} \times \frac{1}{P_e}$$

where E is equal to the net kw-hr. put out by the plant.

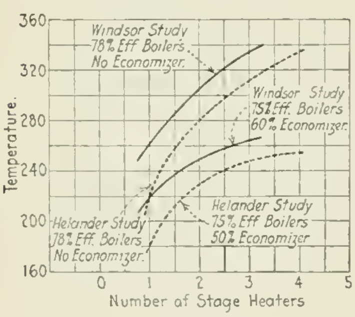

FIG. 8 COMPARISON OF WINDSOR AND HELANDER STUDIES SHOWING THE TEMPERATURE AT WHICH BEST RESULTS ARE OBTAINED FOR VARIOUS-STAGE BLEEDING

Where the plant was equipped with economizers and induced-draft fan, and a motor-driven boiler-feed pump was used, the plant-auxiliary power requirements were assumed to be 1600 kw. and E was equal to 28,000 — 1600 or 26,400 kw-hr. Where a turbine-driven boiler-feed pump was used, the plant-auxiliary power requirements were assumed to be 1400 kw. and E was equal to 28,000 − 1400 or 26,600 kw-hr.

In case the large boiler is used without the economizer, the rise in the economizer is neglected in the last two equations, and the boiler efficiency is taken from Fig. 3 instead of Fig. 2.

Where the high boiler is used with natural draft the boiler feed-pump requirements are reduced from 200 to 175 kw. and the auxiliary power is reduced 150 kw., on account of the omission of the induced-draft fan.

In case the steam-turbine-driven pumps are operated, Item C is increased by the amount of heat in the exhaust steam. In arriving at the B.t.u. in the exhaust steam, allowance was made for variations in back pressure by increasing the water rates of this unit $1/2$ per cent per pound increase of back pressure.

A great many of the above factors are constant, and only a few change so that when one is familiar with the method the points on the curves can be obtained at the rate of two or three per hour.

Fig. 6 is a study of single-, double-, and triple-stage heating for the Windsor turbines, in combination with a 20-tube-high boiler having an efficiency of about 78 per cent at the point at which it is operated.

Curve 1 shows the results obtained with single-stage bleeding.

Curves 2 and 3 show the results obtained with double-stage heating. There is apparently very little difference whether the thirteenth or fourteenth stage is used as the first stage.

Curve 5 shows the results obtained with triple-stage heating, the best being those obtained by a combination of the fourteenth, eleventh, and eighth stages. It is possible that a higher stage might be slightly more efficient, but the data therefore were not available.

Fig. 7 is a comparison of the results obtained by Mr. Helander for various-stage bleeding with the results of the Windsor study. Mr. Helander limited his study to four stages, but the curve is projected so as to show the approximate results for five stages. The Windsor study was made for three stages, but is extended so as to indicate the approximate results for four stages.

Fig. 8 shows the temperature at which the best results were obtained for single-, double-, and triple-stage bleeding in the Winsor study and single-, double, and quadruple-stage bleeding in the Helander study.

These studies clearly indicate the advantage of bleeding the main unit with or without economizers, there being a gain of 1.10 per cent for double-stage over single-stage heating and approximately one half that amount if triple-stage is used in place of double-stage heating, that is, for a 14-tube-high boiler equipped with economizer; whereas for a 20-tube-high boiler there is a gain of 1.64 per cent in double-stage heating over single-stage, and about 1.00 per cent if triple-stage heating is used in place of double-stage.

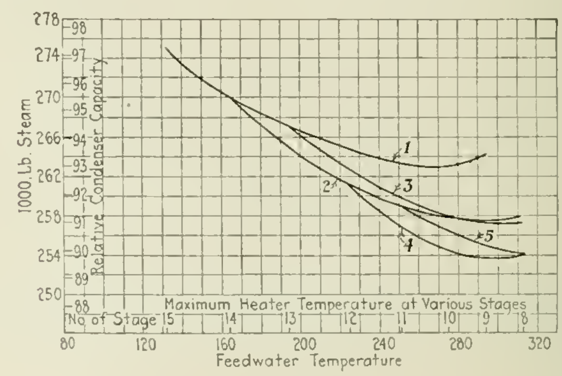

FIG. 9 AMOUNT OF STEAM PASSING TO MAIN CONDENSER AND RELATIVE SIZE OF MAIN CONDENSER REQUIRED

Regarding reliability, while the heater condensers will complicate the condensate piping and increase the pumping head, with the possible exception of the effect of breakage of extraction heater tubes, it is difficult to see how they will affect the reliability of the plant or complicate the operating problems. The breakage of a condenser tube can be taken care of either by installing check valves between the heater and the main unit, or in the lower-stage heaters by putting in drip lines of large enough capacity to take care of possible leakage. Condensate that leaks through a broken tube in this way is returned to the condenser or condensate system, and is not lost. Gate valves should be installed between the heater and the main unit so that the heater can be disconnected from the unit if desired.

Regarding the capacity of condensing equipment, as the bleeding of the main unit reduces the amount of heat passing to the main condenser, some reduction in its size is permissible. Fig. 9 shows the pounds of vapor and condensed steam entering the main condenser per hour for various bleeding combinations. This study indicates that for single-stage bleeding the condenser capacity need only be 93 per cent of that required if steam is bled from the main unit. For double-stage heating this ratio becomes 91 per cent and for triple-stage heating 90 per cent.

Fig. 4 indicates that heating the feedwater by exhaust steam

(Continued on page 429)

Diesel-Engine Progress on the Pacific Coast

By H. W. Crozier, John Stigen, and C. E. Nagel, San Francisco, Cal.

Diesel designers and builders on the Pacific Coast have been making important strides in the development of the full Diesel engine, particularly since they have resolutely turned from the so-called semi-Diesel engine, dependent for ignition of the fuel on a hot surface, and have concentrated their efforts on the true Diesel type, which uses only the heat of compression for that purpose. The bravery of these men in departing from European precedents in simplifying and strengthening the designs of their engines and their daring in using thousands of pounds pressure in attaining a solution of the mechanical solid-injection problem have resulted in the construction of splendidly satisfactory engines, a feat of which the profession may well be proud.

As an indication of the quality of the engines produced, practically all manufacturers fit forced-feed lubrication through drilled holes in crankshafts and drilled holes through connecting rods, insuring ample lubrication of the bearings, with resulting long life. Cylinder lubrication has careful attention and individual feed lines running to each cylinder from McCord-type force-feed lubricators are practically universal. No dependence is placed on splash, as forced feed is fitted to camshafts, timing gears, and other similar parts. Circulating pumps are nearly always direct-connected and in duplicate, and the prevalence of the marine demand necessitates use of brass and other high-grade metals suitable for salt-water service.

Favorable to the extended use of Diesel engines is the ample supply of suitable fuel, assured for many years to come, and an informed public accustomed to the extensive use of carburetor-type internal-combustion engines. True Diesel engines are being manufactured in increasing quantities and are being introduced for practically every mechanical purpose. Marine service has taken by far the largest proportion of the production, but stationary service is not neglected by any means. The whole range, from the smallest to the largest, and of good quality, is obtainable from one or more of the six or eight prominent manufacturers. In adaptability to new uses the Pacific Coast is leading along certain lines, particularly in the use of small and moderate-sized engines in heavy-duty marine service.

A Large Stationary Diesel-Electric Generating Set[1]

The recent shipment from Oakland, Cal., of a large stationary Diesel engine marks a forward step in California Diesel practice as it is the largest engine so far supplied for electric service.

This Diesel-electric unit consists of a six-cylinder, four-stroke-cycle, $20^1/_2$-in. by $35^1/_2$-in., 150-r.p.m., Pacific Werkspoor Diesel engine, direct-connected to a 925-kva., three-phase, 60-cycle, 2400-volt, Westinghouse alternating-current generator, with direct-connected exciter, and goes to the electric central station of the Tucson (Ariz.) Gas, Electric Light, and Power Company for installation as the fifth Diesel-electric unit.

It will run in parallel with four 500-b.hp. Diesel-electric units, each having direct-connected alternating-current generators and with 870 kw. of Corliss non-condensing steam-driven equipment used for standby and to assist over the peaks.

Of the crosshead type, so called, which has been so successful in the large sizes at sea, the new engine is materially different and much simpler than the four operating units at present in operation, which are all of the conventional trunk-piston type. Complete separation of the cylinder and engine lubricating systems and elimination of the oil contamination by discharges from the cylinders; simple and efficient piston cooling piping; ease of inspection of all operating parts while running, and ease with which pistons and piston rings may be inspected or removed, are some of the advantages of the crosshead type.

One of the important features of the design is the accessibility of the piston and piston rings. The cylinder is in two parts. The upper part includes practically all of the cylinder exposed to the hot gases; the lower part or skirt, mates with the upper in a stepped ground joint. With the piston on the lower dead center, removal of eight bolts permits lowering of the skirt, thereby exposing the piston and rings, for inspection or removal of rings. If the bolts holding the piston have been previously taken out, the piston may be removed from the engine in its entirety; all this of course without dismantling any other part of the engine.

Tucson has a high-grade circulating-water cooling system in service, which has been extended to supply the new engine. Its particular feature is the use of clean or distilled water in a closed circuit consisting of the engine jackets, heat-exchanger coils placed in the cooling towers, and a motor-driven circulating pump (in duplicate). The object attained is the prevention of scale on the cylinder cooling surfaces.

This engine was given a 24-hour full-load continuous test by the builders and the following performance data were obtained, the power being measured by a hydraulic brake:

Average output		562 kw. or 847 b.hp.
Indicated power of all 6 cylinders		1185 i.hp.
Average mean effective pressure		96 lb. persq. in.
Compressor:		
Low-pressure cylinder (15 lb. m.e.p.)	17 i.hp.	
Int.-pressure cylinder (57 lb. m.e.p.)	16 i.hp.	
High-pressure cylinder (386 lb. m.e.p.)	16 i.hp.	49 i.hp.
(Compressor i.hp. = 4.2 per cent of main engine i.hp.)		
Average fuel consumption		0.43 lb. per b.hp-hr.

For the moderate-sized units a station duty of 0.72 lb. per kw-hr. generated may be expected, corresponding to 0.47 lb. per b.hp-hr. Larger sizes comparable to the new engine may be expected to have a station duty of 0.67 lb. per kw-hr. or 0.415 lb. per b.hp-hr.

Lubricating oil will be required at the rate of about 1375 kw-hr. per gal. for trunk-type engines, but the larger engines, particularly of the crosshead type, have a higher lubricating oil economy and may reach 2000 kw-hr. per gal. if intelligently operated.

Pacific Coast Experience with Large Diesel-Engined Motorships[1]

It is but natural that the many advantages claimed for the Diesel engine should attract the attention of both the engineers and business men who have the present as well as the future welfare of the shipping industry in their charge. For marine work this type of motive power seems particularly adapted, especially in cases where the total horsepower required is not excessive. The simplest and most reliable arrangement for a marine steam power plant appears to be the Scotch marine boiler with marine superheaters and the triple- or quadruple-expansion engine, with which a total fuel-oil consumption of 1.25 to 1.40 lb. per shaft hp. is a fair average for up-to-date plants. When, then, the Diesel-engine advocate comes along claiming a fuel-oil consumption of from 0.38 to 0.45 lb. per shaft hp., it is no wonder that the man who holds the destiny of so vital an industry as our merchant marine should take notice. Besides this great fuel economy, the advantage of which increases with the increase in length of voyage, there are other features of the Diesel engine which prove a decided advantage when applied to a marine power plant. Among these are the instantaneous availability of full power at a moment's notice, without any special preparation; quick reversal from full speed ahead to full speed astern; immediate shutdown of engine in cases of emergency; a greater number of operating days per year, due to avoided delay in boiler cleaning and annual inspection; an increase in cargo capacity, due to reduced bunker oil required; and a reduction in the number of the crew, as no firemen are required. Against these advantages must be charged the disadvantages of a higher first cost, with the attendant increase in depreciation and insurance, a higher lubricating-oil consumption, and a smaller

Presented at the Pacific Coast Regional Meeting of The American Society of Mechanical Engineers, Los Angeles, Cal., April 16 to 18, 1923. Abridged.

[1] By H. W. Crozier, who also prepared the preceding introduction and the remaining portions of the paper not otherwise credited. Mr. Crozier is engineer with Sanderson & Porter, San Francisco, and a member of the A.S.M.E.

[1] By John Stigen, naval architect, Standard Oil Co. of California.

field from which to select the men to care for the plant. In view of these facts it is rather surprising that there are not more Diesel-engined motorships in the American merchant marine.

On the Pacific Coast the Standard Oil Company (Cal.), with which the writer has the privilege of being connected, has taken a leading part in introducing this type of motive power in the marine service.

In November, 1920, this company put in commission its first motorship, the *Charlie Watson*, a tanker of about 2135 dead-weight tons, propelled by two 550-b.hp. Pacific Werkspoor Diesel engines. A year later, a second motorship, the *H. T. Harper*, a tanker of 4700 deadweight tons equipped with two 850-b.hp. engines of the same make, was added. This vessel, as far as principal dimensions and lines of hull are concerned, is an exact duplicate of the Company's *El Segundo*, which has two Scotch marine boilers and a triple-expansion engine developing 1850 i.hp.

The fact that after two years' continuous operation of its Diesel-engined ships this company in July, 1922, placed an order for a third vessel with Diesel power should be sufficient proof that they regard their motorship enterprise as a success. This last vessel, which is now being completed, is a Diesel-electric tanker of about 1875 d.w. tons, equipped with two 400-b.hp. Pacific Werkspoor Diesel engines connected to direct-current generators which in turn supply power for a 600-b.hp. motor coupled direct to the propeller shaft. The vessel is designed for bay and harbor service as well as coastwise, and the Diesel-electric type of propulsion with direct pilot-house control was selected as particularly well adapted for this kind of work where a great deal of maneuvering has to be done.

The question of machinery weights is often quoted as being against the Diesel engine. This may or may not be correct, depending on the engines themselves, and also upon how much and what kind of auxiliaries are selected. With all capacity requirements equal the machinery weights of a motorship will approximate very closely those of a steamer, and should never exceed them by more than 10 per cent. This increase in machinery weights, however, is more than offset by the reduction in fuel oil required for any given length of voyage.

Basing our figures on the total fuel oil consumed for all purposes aud the shaft horsepower developed, the fuel consumption per shaft horsepower per hour will be 1.35 lb. for the steamer *El Segundo* and 0.475 lb. for the motorship *H. T. Harper*. A correction must be made here to take care of the increase in the horsepower required due to reduced propulsive efficiency of the twin-screw installation of the motorship, which will bring the fuel consumption to 0.51 lb. per hp-hr.

This shows a decided advantage for the Diesel engine for propulsion, but in comparing the port consumption which takes in power used for discharging the oil cargo as well as for all other purposes, we find that the motorship, with its electric auxiliaries, performs this work with a fuel consumption of from 15 to 20 per cent of that required by the steamer.

Diesel-Electric Ferry, San Francisco Bay

San Francisco Bay has been noted for the high-class ferry service given with the fast, clean, and commodious ferry boats plying its waters. These are of the double-ended, two-deck type and are, with the exception of the new Diesel-electric ferry, *Golden Gate*, propelled by steam, several types of steam propelling machinery being used.

Diesel engineers attacking the problem of the San Francisco Bay ferries were astonished to find that the old walking-beam, low-pressure, jet condensing engines, noted as they are for their reliability and maneuvering qualities, are at the same time the most economical on the bay.

On the $4\frac{1}{2}$-mile route between Hyde street, San Francisco, and Sausalito, service is given with the Diesel-electric ferry running 16 hours and the steam ferry running 12 hours daily, the fuel consumptions being 5 gallons and 14 gallons per mile, respectively. Under construction at Los Angeles are two new steam turbine-electric ferries with double-end propellers which are expected to have the good economy for steam of about 30 gallons per mile. A Diesel-electric installation in this size ferry would use around 14 gallons per mile.

The Diesel-electric ferry *Golden Gate* has been running long enough for her merits to be recognized. She is particularly good in manoeuvering ability, accelerates rapidly, and on the whole is an exceedingly economical and profitable investment.

Her machinery consists of two Pacific Werkspoor Diesel engines, each direct-connected to 360-kw. 250-volt direct-current generators with direct-connected exciters which furnish current to drive the 500-volt propeller motors each of 750 b.hp. Kingsbury thrust bearings are fitted. The after propeller does most of the work of propelling the boat, and the leading one is controlled to operate at reduced speed and practically idles, consuming from 10 to 15 per cent of the power. This arrangement results in good economy because it is possible to design the propellers for the best operating conditions.

The ferry is usually operated directly from the pilot house. It may be thrown over from full speed ahead to full speed astern while under way, and the machinery responds immediately.

The combination of the electric drive with the advantages of speed control to get high propeller efficiency and the Diesel engine with its high fuel economy and reliability makes an excellent arrangement, and it is expected that many more Diesel-electric boats will be built. A second ferry, the *Golden West*, is nearly ready for its trial trip.

The 18,000 B.Hp. of Diesel Engines Built in Oakland, Cal.[1]

An important impulse was given to the Diesel industry on the Pacific Coast by the United States Shipping Board Emergency Fleet Corporation in awarding a contract for twenty 850-b.hp. Diesel marine engines to be built on San Francisco Bay, later reduced to 10 engines after the armistice was signed. Engines were constructed in accordance with this contract under the Dutch Werkspoor patents, but differed from the Dutch designs in having strong cast-iron pedestals in place of the characteristic steel diagonal rods of the Werkspoor design, resulting in a much stiffer engine.

The first engine was given a 32-day continuous test run under full load, and to show the good condition in which the engine was at the end of this run, a 20 per cent overload was put on for several hours before stopping. This engine and a second one, to make a pair of engines, were, with the permission of the Emergency Fleet Corporation, sold during construction to the Standard Oil Company of California, and were installed in the M.S. *H. T. Harper*.

Substantially the same design, now designated as the Pacific Werkspoor design, was followed for two 600-b.hp. engines for the motorship *Charlie Watson* and two 400-b.hp. engines for the Diesel-electric tanker *Standard Service*, all for the Standard Oil Company of California.

The ten engines built for the Emergency Fleet Corporation were sold by the Corporation several months ago, the first one being the engine described by Mr. Crozier for the installation at Tucson, Ariz. Two were secured by the Standard Oil Company of California, and the remainder by various Pacific Coast marine interests.

One of the three purchased by the Lynch and Grey interests has already been installed in the *Frank Lynch*, a Great Lakes type vessel from which the steam plant was taken out. In this installation while under way at sea the exhaust gases from the Diesel engine are passed through a steam boiler, which generates steam for the steering engine and electric-lighting equipment.

The 850-b.hp. and 600-b.hp. engines are of the large, slow-turning crosshead type, but many of the smaller trunk-piston type, the smallest so far being a 70-b.hp. two-cylinder engine, have been built, two of the latter size going to a gold dredge operated in Alaska.

Of the large-size trunk-type engines which have been built and installed on the Pacific Coast, the following are of interest:

A set of three 525-b.hp. engines in a Diesel-electric power station in Nome, Alaska, where the electric power is carried to floating gold dredges through an overhead cable. Two of this same power are in operation on the Diesel-electric ferry *Golden Gate* running between San Francisco and Sausalito. Another pair of these engines is being installed in a sister ship the *Golden West* now being built for the same company and which will soon be in operation. One of these 525-b.hp. engines is being operated in the Columbia River territory.

[1] By C. E. Nagel, chief engineer, Pacific Diesel Engine Co., Oakland, Cal.

The 250-b.hp. engine in four cylinders is another popular size of which many have been installed.

On the whole, there has so far been built 18,000 b.hp. of full Diesel engines in one shop in Oakland, Cal., not a bad record by any means.

Small Marine Motors

The Pacific Coast uses literally thousands of small motorboats fitted with gas engines ranging from the 6-hp. outfit of the crab fisherman through the 80- to 150-hp. launches to tugs of 300 hp. and upward. Designed to operate on the California distillate, a semi-volatile liquid fuel one step downward on the scale from common gasoline, the marine gas engine, usually designated as the Pacific Coast type, is a rugged, heavy-duty, reliable and substantially built machine.

These machines are built in quantities by a dozen or so manufacturers and the gas-engine industry is of considerable importance. Imagine the consternation two years ago when the oil companies, forced by scarcity of suitable refining crudes coincident with increasing demands for gasoline, had to withdraw distillate from the market and were only able to supply gasoline at two and a half times the price.

With twenty years or so of experience back of them in building marine motors to meet the severe Pacific Ocean conditions, what was more logical for the builders than to turn to the Diesel engine for the solution of the problem and to develop from the various types something which would fit the demand.

Increasing quantities of Diesel engines are now being manufactured which are operated on the four-stroke cycle with mechanical airless injection, using an oil pressure of around 4000 lb. per sq. in., and which also have all the excellent features of the marine gas engine, which they are rapidly superseding, being in essentials but little different. The oil-injection pressure is obtained by a two- or three-plunger pump driven off the camshaft and fitted with a relief valve for limiting the pressure. Some engines are fitted with an accumulator also. For idling at reduced speeds means are provided to reduce the injection pressure to 2000 lb. per sq. in. or even to 1500 lb.

The high-pressure oil is injected into the cylinder through an injection valve of the needle type which has a removable tip drilled with a number of small holes ranging from 0.006 in. to 0.01 in. in diameter in the various designs. Regulation is obtained by varying the lift of the injection-valve needle. To facilitate maneuvering all engines are fitted with governors.

A compression of approximately 420 lb. per sq. in. is usual and 390 lb. is the operative minimum below which ignition is uncertain. Pressure during burning of the fuel varies from 450 to 500 lb. per sq. in. and the conditions are in general like those which obtain in the air-injection engine, save that the horizontal admission line of the indicator card of the air-injection engine is usually not realized.

Like the larger Diesel engines, starting is by compressed air, and a small single-acting compressor cylinder is fitted to furnish a supply sufficient for several starts, a small tank being supplied.

As a general rule the marine fraternity has taken well to the new engines and generally the opinion appears to be that they are thoroughly reliable and dependable and easier, if anything, to take care of than the gas engines which it has used for so many years. The great economy in both fuel and lubricating oil is of course an exceedingly important factor.

The fuel supplied by the oil companies as Diesel oil is designated as 24 deg. B., but is sometimes much lighter. The engines will operate on heavier oils, and in fact on practically any clean suitable oil if it is heated to increase the limpidity, although this is not done to any extent as yet.

As Diesel fuel costs around $3^1/_2$ cents per gallon, the fuel consumption of a 100-b.hp. launch working ten hours a day will be about $11 per week as compared to $50 per week with distillate and $100 per week with gasoline. Parenthetically it may be said that distillate is again available since the bringing in of the phenomenal oil fields in Southern California.

Lubricating-oil consumption at the rate of 1 gal. per 1000 b.hp. is claimed, or about half that of the gas engines, which were heavy consumers of lubricants.

Effect of Altitude on Engine Capacity

Whenever inland Diesel installations are contemplated the question of the effect of altitude on the capacity of the engine arises, and in Pacific Coast practice this is of considerable importance because of the high altitudes of our inland states in the Sierra and Rocky Mountain regions. This effect is easily calculated as it is due to the reduction in the weight of air which enters the cylinder at each stroke because of the lower pressure of the atmosphere at higher altitudes. The reduction in capacity of the engine is about $3^1/_2$ per cent for each 1000 feet elevation above sea level, and is not usually taken to account for altitudes up to 1000 feet.

At Tucson, Ariz., for example, altitude 2440 ft., the normal barometer is 27.34 in. as compared to 30 in. at San Francisco, and the atmospheric pressure is 13.4 lb. per sq. in. as compared to 14.7 lb. at San Francisco. In a Diesel engine having a normal compression of 460 to 480 lb. per sq. in. at San Francisco there would be a reduction of this pressure of about 50 lb. In the installation being made at Tucson this is compensated for by making the piston rods slightly longer.

Compensation for the loss in capacity can be made in various ways and for the first few thousand feet is effected in part by making use of the excess capacity of the engine over full rated load, and by making up in part by increasing the amount of injection air used. This is regularly done at Tucson, and is one of the advantages of the air-injection system.

When altitudes of 5000 ft. or more are encountered, an engine may be run up to its full sea-level rating by adding an air compressor and supplying air at a few pounds pressure to the air inlet valves or by using an electrically driven rotary pressure blower, which will raise the pressure about three pounds per square inch.

Diesel Engines for Agricultural Purposes

Waiting for solution by Pacific Coast engineers is the problem of applying of Diesel engines to agricultural purposes, particularly to tractors. Working on an average of 250 days per year as against 20 days per year in eastern usage, California-manufactured tractors have reached a high stage of development.

The farmer needs the benefit to be obtained from use of the cheaper Diesel fuel and also relief from the ever-present crankcase contamination which plays such havoc with his lubricating oil and bearings; and for tractor purposes a high-speed light-weight engine must be developed having all the excellencies of the present new tractor designs and about the same weight.

In Arizona, Nevada, and the inland mountain country where hydroelectric transmitted power is only available in certain territories, large numbers of Diesels are being bought for pumping, a service requiring reliability and durability, and in particular an efficient oiling system covering every bearing so that no attention is required for days or weeks.

Summary

The Diesel industry in California is now manufacturing and supplying engines from 50 b.hp. up to 1000 b.hp. and can handle even larger types, of which satisfactory service records are available. It has built about 40,000 b.hp. to date. Doubtless the limits given above as already attained will be extended both upward and downward. Its great need at present is the confidence of the public in what it is in a position to deliver, and the assurance of the owners that the engines they purchase will be given fair treatment and necessary attention. The general education of the public as to the internal-combustion engine of the automobile and the steadily growing example of Diesel engines of the smaller sizes on the Pacific waters in the hands of fishermen and others of but limited mechanical knowledge will soon create a spirit of confidence which will wipe out the uncertainty which still persists.

While but little has been done in building large Diesel-engine electric central stations of a magnitude similar to the steam plants of the large power companies, there is nothing to prevent its being done, with profit both to the buyer and the builder. It may be pointed out that a Diesel-electric power plant of 10,000 kw. capacity need have no more than forty cylinders in operation to carry full load. Such a station could give instantaneous stand-by service, or, if sufficient reserve units were installed, would be an economical source of primary power.

Canadian and American Engineers Coöperate to Make A.S.M.E. Meeting a Success

Wholehearted Canadian Hospitality, Excellent Technical Sessions and Unusual Entertainment and Excursion Events Make 1923 Montreal Spring Meeting Memorable

THE Spring Meeting of The American Society of Mechanical Engineers, held in Montreal May 28–31, was featured by an interesting program of technical sessions, industrial visits, and entertainments. The registration for the meeting was 631, which included 149 members of the Engineering Institute of Canada and 120 ladies. Although this number was not large compared to the Chicago meeting of 1921 or the Detroit meeting of 1919, it must be remembered that numbers have very little to do with the success of a Spring Meeting; every one who was at Montreal enjoyed it thoroughly and will testify to its successful attributes.

The entertainment and excursion events were conducted in an excellent manner and everywhere there was praise for the Local Executive Committee, made up of H. H. Vaughan, Chairman, Major J. A. Duchastel, Vice-Chairman, Fraser S. Keith, Secretary, and Fred. B. Brown, John T. Farmer, George R. MacLeod, and Major C. M. McKergow. The unusually large number of ladies at this meeting made the entertainment features very enjoyable. The ladies were received by a committee made up of the wives of the Local Executive Committee, with Mrs. Fred. B. Brown as chairman. The *A.S.M.E. News* of June 7 contained an account of the entertainment and excursion features.

The feature of the technical sessions at Montreal was the wholehearted manner in which the engineers of Canada coöperated in the meeting. Of the seventeen papers presented at the meeting, seven were written by Canadians, and their contribution to the program will have a notable effect in increasing the understanding by Americans of the problems and progress of the Canadian engineer. The American Society of Mechanical Engineers was fortunate to have on its program such exponents of hydroelectric power development as Julian C. Smith of the Shawinigan Water and Power Company, and Frederick A. Gaby of the Hydro-Electric Power Commission of Ontario. H. G. Acres, of the Ontario Hydro-Electric Power Commission, presented an exceedingly interesting paper on large hydraulic turbines. Fred W. Cowie, Chief Engineer of the Montreal Harbor told of the remarkable accomplishments in the harbor of Montreal. J. A. Wilson, General Secretary of the Canadian Air Board, explained the progress made by the Canadian Government in encouraging and regulating aviation. The two papers on the program for the Railroad Session were presented by Canadians, H. R. Naylor of the Canadian Pacific Railroad and C. E. Brooks of the Canadian National. In this manner, therefore, the Canadian engineers coöperated most wholeheartedly and substantiated the sentiment expressed by the President of the Engineering Institute of Canada in his opening remarks that the engineering profession, as such, recognized no international boundary.

The Council of The American Society of Mechanical Engineers was very well represented at the meeting, there being only four absentees. However, there were nine past-presidents on hand for the deliberations and for the enjoyable dinner which was tendered by the Council of the Engineering Institute of Canada to the A.S.M.E. Council.

Business Meeting

THE first session was the Business Meeting of the Society, held Monday afternoon, May 28. Walter J. Francis, President of the Engineering Institute of Canada, spoke a few words of warm greeting on behalf of the engineers of Canada and emphasized the community of interest among engineers. President Harrington responded in kind.

The only matter of business was the announcement of Cleveland, Ohio, as the place for the 1924 Spring Meeting of the Society. John Price Jackson, Mem. A.S.M.E., and Executive Director of the Sesqui-Centennial Exposition to be held in Philadelphia in 1926, was then introduced. Mr. Jackson explained the importance of the coming exposition not only as a record of the remarkable advances in science and industry in the immediate past but as an inspiration for tremendous new advances.

The business meeting was then turned over to Calvin W. Rice, Secretary of The American Society of Mechanical Engineers, who delivered his travelogue on his trip to South America, when he bore credentials from the Engineering Institute of Canada to the South American Engineering Congress. This was the first opportunity given to members of the Engineering Institute of Canada to hear the report from the Congress and the account of Mr. Rice's trip through South America.

First Power Session

PROF. A. G. Christie of Johns Hopkins University, Past Chairman of the Power Division and Member of the Council, A.S.M.E., called the first Power Session to order on Tuesday morning, May 29, and introduced Philip S. Gregory,[1] who presented the paper by Julian C. Smith, Chief Engineer of the Shawinigan Water and Power Co., on Power Development in the Province of Quebec. Mr. Gregory was followed by Fred A. Gaby, Chief Engineer of the Hydroelectric Power Commission of Ontario, who presented the paper on the development of Hydroelectric Power Plants in Ontario. These two papers and the discussion contributed by F. Darlington of New York,[2] John R. Freeman[3] of Providence, and William M. White[4] of Milwaukee, appear in generous abstract on preceding pages of this issue of MECHANICAL ENGINEERING. The program for this session was arranged for the Power Division by the Montreal Committee.

Management Session

DEAN Dexter S. Kimball, Past-President of the A.S.M.E., wielded the gavel at the Session on Management, Tuesday morning, May 29, the program for which had been provided by the Management Division.

The paper by R. B. Wolf[5] on Management Engineering in the Paper Industry was read first. This paper appeared in the May issue of MECHANICAL ENGINEERING. The discussion on Mr. Wolf's paper was opened by L. W. Wallace,[6] who agreed with Mr. Wolf that the most difficult problem in installing improved management methods was in overcoming the non-response of superintendents and foremen. Mr. Wallace also agreed that a correct approach to the solution to this problem was the stimulation of interest in production achievements and costs. He emphasized the need for measuring the performance of the individual operators and the provision of an adequate avenue of self-expression for the individuals in industry.

Wallace Clark[7] agreed in the main with the statements made by Mr. Wolf but he pointed out that while departmental cost sheets are practical in continuous industry, they are difficult to secure in a non-continuous industry, where the cost of idleness is not maintained separately from the cost of work done. Mr. Clark also emphasized the need of translating costs to time, which is an element which the operator understands. He knows that he should accomplish a certain amount of work in a certain time;

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[2] Cons. Engr., 165 Broadway, New York.
[3] Pres. Mfrs. Mut. Fire Ins. Co. Past-Pres. A.S.M.E.
[4] Mgr. Ch. Engr., Hyd. Dept., Allis Chalmers Mfg. Co Mem. A.S.M.E.
[5] R. B. Wolf Co., New York, N. Y. Past Vice-Pres., A S M.E.
[6] Exec. Sec., Federated American Engineering Societies, Washington, D. C. Mem. A.S.M.E.
[7] Indus. Engr., New York, N. Y. Mem A.S.M.E.

and if the time he consumes is compared by the Gantt chart with some sort of standard of time necessary, great improvements in operation will result. Mr. Clark stated that the important factors to be evaluated are whether the machines are running and whether operators are doing their work within an estimated time.

In answer to a question as to the cost of clerical work for a cost system, Mr. Wolf stated that in one particular plant by adding $13,000 a year to the engineering and clerical force, the first year's actual saving was approximately $40,000.

In closing the discussion Mr. Wolf admitted the difficulty of developing departmental cost sheets in a non-continuous process factory. Mr. Wolf did believe, however, that in a department organized for a specific purpose, a measurement of accomplishment was necessary to develop the individuality of the department.

The question of industrial engineering education has always been a prolific source of discussion. The paper by Professor Myron A. Lee[8] on a Practical Laboratory and Drawing-Room Course in Industrial Engineering, was no exception and discussion was contributed by a large number of educators and industrial engineers. Professor Lee's paper, with the discussion, will appear in the August issue of Mechanical Engineering.

The Railroad Session

The Railroad Session with the program prepared by the Railroad Division was presided over by H. H. Vaughan, Member of the A.S.M.E. Council. The first paper presented was by H. R. Naylor,[9] on Steel Car Construction at the Angus Shops of the Canadian Pacific Railroad. This paper appeared in the June issue of Mechanical Engineering. In the discussion Ernest R. Viberg[10] stated that the box car is one of the most important element of stock equipment used by the railroads. He ventured to guess that the railroads of Canada and the U. S. used about 250,000 box cars of the steel-frame, single-sheathed type.

F. O. Whitcomb,[11] discussed the subject of car construction from the point of view of the contract shop. The diversity of types and sizes of cars and the small orders executed at one time at such a shop precluded the spending of money on large special tools. The railway men could work with the car designer and build the cars around existing tools. Mr. Whitcomb believed that the jig method of assembling freight cars was more expensive than the skid method, in which in six positions the underframe was sheathed and assembled, then placed on its own trucks and in ten moves was ready for the woodwork. Under such an arrangement an average of forty-two cars per day for over a month had been made, with 52 in one day of eleven hours as the maximum. Mr. Whitcomb mentioned the use of electric rivet heaters as a desirable economy and endorsed the continuous painting machine described by Mr. Naylor. Max Toltz[12] expressed the opinion that the dead weight of the car could be considerably reduced, for reducing dead weight was necessary if greater economy of operation was to be attained. Mr. Toltz recommended the consideration of alloy steel in cars under construction. Augustus Smith[13] pointed out the need for designing bodies of cars that would lend themselves more readily to handling contents mechanically.

In closing the discussion, Mr. Naylor expressed the opinion that by use of the jig method a tighter box car is secured, and in enumerating the various moves under the system of jig assembling, he found only six. Mr. Naylor reported that electric rivet heaters were not found satisfactory. He also stated that the proportion of dead weight to limit loads in steel box cars had not increased as the size increased.

The paper by C. E. Brooks[14] on More Recent Developments of the Motor Coach treated of a subject which is only in the earliest stages of development but covers a large field and variety of equipment. Mr. Brooks' paper precipitated a discussion as to the relative merits of the gasoline motor car and the electric storage-battery car. The paper with the discussion will appear in the August issue of Mechanical Engineering.

Second Power Session

A. G. Christie, Member of Council, A.S.M.E., presided Wednesday, May 30, at the second session under the auspices of the Power Division. Two papers were presented: the first, by H. G. Acres,[15] was entitled Modern Hydraulic Turbines of Large Capacity, and the second, by Peter Payne Dean,[16] Sectionalization and Remote Control of High-Pressure Steam Lines. Mr. Acres' paper brought out considerable interesting discussion on the various mechanisms in use in modern large-capacity hydraulic power plants. The paper will appear in the August issue of Mechanical Engineering with the discussion, as will also the paper by Mr. Dean and its discussion.

Port Development

The program on Port Development was arranged by the Materials Handling Division, and its chairman, H. V. Coes, presided at the session on Wednesday morning, May 30. The first speaker was Fred W. Cowie,[17] who gave a broad outline of the port development of Montreal. Mr. Cowie has served as chief engineer for the Montreal Harbor Board for sixteen years and is recognized as an authority on transportation and harbor development. A second paper was presented by Carroll R. Thompson, Assistant Director of Wharves, Docks and Ferries of the City of Philadelphia. Mr. Thompson's paper was a résumé of the papers presented under the auspices of the Materials Handling Division at various Atlantic seaports during the past year. The papers by Messrs. Cowie and Thompson with the discussion will appear in the September issue of Mechanical Engineering.

At the close the chairman presented a report of a committee appointed by the Materials Handling Division to devise a formula which might be used in determining the justifiable investment for labor-saving machinery. The report of the Formula Committee will be presented in the August issue of Mechanical Engineering.

Textile Session

The textile program, arranged by the Textiles Division, consisted of one paper which was presented on Wednesday morning, May 30 with C. R. Main, member of the Executive Committee of the Textiles Division, in the chair. Under the title Bleachery Engineering and Operation, the authors, Frank P. Bascom[18] and J. C. McDowell,[19] explained the extreme complication of the process of converting gray cotton cloth into bleached, dyed, or printed fabric. They emphasized the artistry required by the bleacher, the finisher, and the dyer in working the raw material and producing the final result that would be pleasing and useful to the discriminating housewife. They showed the difficulty of determining the exact amount of starch required merely by the feel of the goods and the exact quantities of dyes to be used. as examples pointing to the need of great experience and familiarity of the bleachery foremen with processing methods. Great care must be exercised. The authors visualized an ideal plant and briefly traced the goods through the various processes. They pointed out that the grouping of operations formerly conducted independently is the most important recent development in the bleaching industry. By the use of variable-speed motors driving the various units, the cloth may be led from one machine to the next and with automatic speed controls the tension of the cloth from machine to machine and process to process may be properly maintained. In this grouping of units for continuity of processing lies the key to rapid production

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[9] Asst. Works Mgr., Angus Shops, Canadian Pacific Ry. Co., Montreal, Can.

[10] Mech. Engr., Canadian Car & Foundry Co., Ltd., Montreal, Can. Mem. A.S.M.E.

[11] Canadian Car & Foundry Co., Ltd., Montreal, Can.

[12] Toltz, King & Day, Inc., St. Paul, Minn. Vice-Pres. A.S.M.E.

[13] Bergen Point Iron Wks., Bayonne, N. J. Mem. A.S.M.E.

[14] Mech. Asst., Canadian National Railroad, Toronto, Can. Assoc-Mem. A.S.M.E.

[15] Hyd. Engr., Hydro-Elec. Power Comm. of Ontario, Niagara Falls, Ont., Canada.

[16] Payne Dean, Ltd., Stamford, Conn.

[17] Chief engineer, Harbor Commissioners, Montreal, Canada.

[18] Supervising Engineer, Lockwood, Greene and Co., Boston, Mass.

[19] Lockwood, Greene and Co.; Boston, Mass

and minimum operating costs. Economical handling of materials is a point of great interest to the plant designer. The provision of proper water is also an item of great importance; for high-class work, many plants require elaborate water-filtering and purifying apparatus. In all problems of bleachery design it is necessary to study local conditions, goods to be treated, the results desired, and apply a thorough knowledge of proper equipment and methods.

Fuels Session

TWO interesting papers presented at the Fuels Session on Thursday morning, May 31, brought forth considerable discussion. The program was arranged by the Fuels Division and the session was presided over by Fred R. Low, chairman of the Division. Chimney Sizes was the title of a paper by Alfred Cotton[20] which was presented at the meeting by E. R. Fish.[21] This paper will be abstracted in a later issue of Mechanical Engineering.

The second paper, on Lignite Char, appeared in the May issue of Mechanical Engineering. In presenting it, O. P. Hood,[22] the author, submitted considerable additional information. He called attention to the apparently abnormal fact that people in some of the western states were living on a bed of fuel and yet burning coal brought from a distance of 1000 to 2000 miles. While comparatively unimportant in ordinary times, this threw an apparently unnecessary burden on the transportation system of the country in time of war, and was one of the circumstances that led to undertaking the investigation described in his paper.

The main difficulty in developing the lignite-char industry at present, he said, was economic. Nobody knew whether the product would find a steady market, and until this had been determined the industry could not be developed. Present stoves and furnaces would not burn it, and there would be no stoves to burn it until there was a lignite char that could be bought freely on the market, and it was difficult to produce the material in quantity until there was a market for it. Furthermore, production of lignite char was supposed to require fairly expensive equipment and this constituted a serious obstacle in two ways. In the first place, no one cared to make the heavy investment necessary for the experimental period in view of the general uncertainty of both the technical and commercial elements of the proposition; and, secondly, lignite mines were comparatively small and it did not appear commercially attractive to put up expensive furnaces in connection with mines of limited output.

This affected the by-product phase of lignite coal manufacture. The business of making lignite char with the saving of by-products was essentially a large-scale business. As such, it required very considerable investments which financial people were not ready to make, particularly as lignite mines were in districts only thinly populated (e.g., North Dakota and Texas) where both the economic and labor conditions were unsuitable for big industrial developments.

Of late, however, the Bureau of Mines had developed an experimental furnace and several hundred tons of char had been produced. The char, in general, was the result of the concentration of about $2^1/_2$ tons of lignite into one ton of char. Whatever ash there was in the original lignite would be found in the char multiplied by $2^1/_2$. The volatile matter in the char was controlled within certain limits but in general ranged from 8 to 12 per cent. The fixed carbon was 65 to 70 per cent, the moisture practically nil. This coincided closely with the analysis of anthracite coal. The grains of char were not as hard as anthracite, were clean, and did not break with weathering. One of the favorable characteristics of char was that there was practically no carbon in the ash, in addition to which the char had the ability to hold the fire and burned out very much as a piece of charcoal did. Lignite char ignited much easier than anthracite—in fact, the fire could be started with paper. .

All that was necessary to make char was to heat the lignite. The moisture came off first; then if heating was continued to a higher temperature, volatile matter began to come off.

The lignite char when burned in a base burner gave service comparable with anthracite coal, but required an adapter on the ordinary grate of the base burner. Efforts to obtain a similar simple solution to the cook-stove problem and the house-heating furnace had not succeeded, and apparently an entire remodeling of the two furnaces would be required to fit them for burning char.

It was possible to produce lignite char at the mine at about \$5 per ton, allowing \$1.50 to the mine operator for his slack, and obtaining at this price a fuel of 12,000 B.t.u. per lb. This made the proposition worth serious consideration.

Max Toltz,[23] among other things, called attention to the developments in lignite and brown-coal utilization in Germany resulting from the pressure of economic conditions. Their central power plants were built adjoining lignite deposits so that the mined fuel could be supplied to the grate of the boiler without being stored, for storage disintegrated or slacked this fuel. In one of these central stations which delivers electrical power to cities within a radius of 120 miles, the majority of the boilers were equipped with step grates upon which the lignite was burned successfully. Chain-grate stokers were also used, but care was required as part of the finer lignite would sift through the grates into the ashpit. This station consumed 900 tons of brown coal every 24 hours.

Another successful appliance for using lignite under boilers was a combination of a semi-gas producer and step grates. The furnace was of the Dutch-oven type projecting in front of the boiler which had a gas-producer chamber partitioned off from the lower step grates by a wall and arch with an opening in the top through which the gases escaped into the combustion chamber over the step grates. The lignite was not fully consumed in the producer, but fell through the bottom of the producer upon the step grates where final consumption of the fuel took place.

The gases of combustion from this fuel upon the step grates combined with the gases leaving the producer and were ignited by an arch back of the grates. The process that took place in the producer was nothing less than that of low-temperature carbonizing of the fuel, so that the lignite falling to the grates was practically half coke. The air for combustion was partly supplied by fans under the step grates and partly (after being heated in ducts of the setting) at a point under the back arch. The latter air would mix with the gases of combustion from the grates and from the producer. The following results had been obtained in this kind of longitudinal boiler installation with lignite of 5400 B.t.u. containing 43 per cent moisture and 6 per cent ash:

Evaporation from and at 212 deg. fahr.	6.9 lb.
Efficiency of furnace and boiler	66 per cent
Chimney losses	21 per cent
Losses due to ashes, radiation	12.5 per cent
CO_2	13.5 per cent

It was claimed that when using part of the chimney gases for predrying the lignite a furnace and boiler efficiency of from 75 to 80 per cent had been obtained. The rate at which lignite was burned per square foot of grate per hour was from 60 to 100 lb., and when peat was burned, up to 130 lb. In addition to these processes, other ways had been developed for the recovery of by-products.

The speaker stated further that some months previous a chemist in St. Paul had demonstrated by a laboratory test that North Dakota lignite could be briquetted without a binder after the sulphur had been extracted. No further details could be given regarding this, but it might lead to some briquetting process, which, if successful, would at least take care of the fuel supply of the Northwest for domestic purposes. During last winter about 5000 tons of North Dakota lignite had been shipped to St. Paul and Minneapolis and used for domestic purposes under special instructions given the consumers by the mine owners. Those who had used this fuel had been satisfied with it, although there had been a general complaint regarding the odor arising from its combustion.

In conclusion Mr. Toltz said it was gratifying to report that besides the U. S. Bureau of Mines, the Mining Department of the University of North Dakota as well as the Government of the Province of Saskatchewan were working for better methods of

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[21] Vice-Pres., Heine Boiler Co., St. Louis, Mo. Mem. A.S.M.E.

[22] Chief mechanical engineer, U. S. Bureau of Mines, Washington, D. C. Mem. A.S.M.E.

[23] Toltz, King & Day, Inc., St. Paul, Minn. Vice-Pres. A.S.M.E.

utilizing lignite, and it was hoped that in the near future the value of this fuel as a source of power, domestic or industrial, would be determined so that at least the northwestern part of the United States, as well as the central provinces of the Dominion of Canada, would derive the benefit of their lignite resources which were now practically lying idle.

Leslie R. Thomson of Montreal, Secretary of the Lignite Utilization Board of Canada, told about the Board and its work. It was a body representing the Dominion Government and the governments of the provinces of Manitoba and Saskatchewan, created in 1918 to demonstrate the commercial possibilities of providing a high-grade domestic fuel to compete with American imported anthracite in the Canadian Central West. The problem was limited to the Central West because as one moved westward from Mid-Saskatchewan the decrease in price of fairly good Alberta coal made it impossible for an expensive briquet to compete. The Board was mainly concerned with the production of a high-grade domestic fuel and did not touch the power question.

The problem of handling Canadian lignites was made increasingly difficult by the fact that they were hygroscopic and if exposed to the air after drying reabsorbed moisture to the extent of from 15 to 17 per cent.

Operation based on the recovery of by-products was out of the question in Canada as far as by-products of the fertilizer type were concerned, because, owing to local agricultural conditions, there was no demand for fertilizers. The only by-product likely to have an immediate market was a motor fuel.

The experimental work done by the Board was described in some detail. Several sizes of retorts were built one after another. All gave trouble at first, but were made to produce ultimately. Even now the operation was too expensive and could not be termed commercial, the main troubles being due to poor floor material and lack of a satisfactory refractory. A carbonizer was being erected now.

Certain technical and commercial points had been discovered in the course of this work. It was found that the B.t.u. content of char varied with the temperature of carbonizing, the curve reaching its peak at 1050 B.t.u. The next point was that char could be sold in the Canadian Northwest only if briquetted.

As regarded sizes, the char would pass through a $^1/_8$ mesh and be retained on about 170 or 180.

The only criticisms offered for the future of the retort were the two points mentioned by the author, one of which was that it was necessary to feed it certain screened sizes. In a country where there was a large amount of lignite slack and small sizes it would seem expedient when attempting to make a high-grade fuel to buy the original fuel of the cheapest material. If the retort would not use that, one very large portion of the possible supply would thus be limited. The second criticism was on the fact that although there was provision for a small amount of by-product recovery, the final solution of lignite retorting must be found, especially as the population increased, in a retort that would give the by-products if and when necessary.

E. N. Trump[24] told of what he had seen in Germany in 1913, in particular the type of furnace for carbonizing lignite. This was a cylinder about 12 ft. in length, lined with refractory brick. At the end away from the furnace was a hole through which the air for combustion entered. That furnace gave a long flame of a very high temperature and the lignite going into it was first dried by the heat from the brick and then as it became char it burned by the direct entrance of the air at the other end, which was regulated. The air was not supplied in sufficient quantities to entirely consume the fuel. The arrangement appeared to be superior to the step-grate furnace and used lignite without any previous preparation.

Col. H. D. Savage[25] stated that the simplest and most efficient way of burning lignite was in powdered form. In tests made some years ago, about seven carloads of lignite had been burned in pulverized form without any change in the plant and with an efficiency of about 78 per cent. More recently in another plant five carloads of lignite of good grade from Colorado were burned likewise in pulverized form without any difficulty. According to the speaker, drying of lignite did not seem to be necessary and moisture up to 22 per cent did not create any difficulty in burning lignite in pulverized form. A plant was now being built at Boulder, Col., to utilize that coal with the necessary rating.

In his closure Mr. Hood stated that there did not appear to be any need of processing lignite when it was to be used for steam-making purposes, and mentioned some tests of burning lignite on a chain-grate stoker.

Answering a question as to whether the experimental device used the heat in the gases, Mr. Hood said that the gases left the device at a low temperature. In fact that was one of the troubles encountered; the gases went off at such a low temperature that they did not burn. The smell was too much for the college campus and it was found necessary to raise the temperature of the gases in order to burn it. One speaker had remarked about reducing the sulphur content of lignite—which was, by the way, already low—and thereby obtaining a product which would briquet. It was interesting to put this in juxtaposition with a statement that came from Oregon, where, with their lignite, by the addition of sulphur they were now producing a briquet.

Mr. Hood called particular attention to the fact that what was known in Germany as "Braunkohle," or brown coal, was not the same thing as the lignite found in this country. The distillation of brown coal was very interesting. If one looked at the bed of brown coal as it lay in the ground in Central Germany, one would notice the bonded formation. Some of it was very light, some would be dark cream color, varying all the way from that to a barely distinguishable lighter shade than the black-brown of the main body. It was these special veins or beds that were used for distillation purposes. Instead of mining the whole mass these beds were mined by hand and kept separate from the rest. Some of it would run as high as 13 per cent in paraffin. When it was considered that the moisture content of that was about 50 per cent, it meant a very high percentage of paraffin on a dry basis. That paraffin was the base of a considerable string of products, one of which was the lubricating oils. They were not taking the whole lignite but taking particular pieces. We in America had our own material and problem and must solve it in our own way and not merely import a way from abroad.

Machine Shop Session

On Thursday morning, May 31, the session on Machine-Shop Practice was held with F. O. Hoagland, Chairman of the Machine Shop Practice Division, presiding. The first paper presented was that of C. R. Söderberg[26] on Recent Developments in Balancing Machines. Mr. Söderberg's paper appeared in the June issue of Mechanical Engineering.

In opening the discussion, G. M. Eaton[27] pointed out that the use of balancing machines for electric rotating apparatus has largely been confined to the works of electrical manufacturers. The shop for maintaining electric machinery finds it extremely difficult to balance rotors of machines being repaired. In view of this, Mr. Eaton stated that the aim of the manufacturers should be to reduce the necessary balancing operation to the simplest procedure in keeping with the fundamental requirements. Mr. Eaton also stated the importance of rendering balancing machines available either by installing such mechanisms in centrally located service stations or by the introduction of portable balancing machines. At present it was generally believed that if service conditions were rough, running balance was an expensive luxury and attention was focused exclusively on making the apparatus rugged and the resulting maintenance expense accepted as a necessary evil. This old belief, however, was being shaken by researches into vibration disturbance and resulting fatigue phenomena. Mr. Söderberg's paper was therefore regarded as very timely.

Carl A. Johnson[28] presented a description of the Newkirk balancing machine. C. C. Brinton[29] pointed out that the development

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[25] Combustion Engineering Co., New York, N. Y. Mem. A.S.M.E

[26] Westinghouse Elec. and Mfg. Co., East Pittsburgh, Pa.

[27] Ch. Mech. Engr., Westinghouse Elec. and Mfg. Co., East Pittsburgh, Pa. Mem. A.S.M.E.

[28] Pres., Gisholt Mch. Co., Madison, Wis. Mem. A.S.M.E.

[29] Asst., Supt. Westinghouse Elec. and Mfg. Co., East Pittsburgh, Pa.

of the future should be a line of portable balancing machines where accuracy was essential and production not a requirement. He stated that one type of shaft which had given trouble in obtaining good balancing was the three-bearing type with two rotors on the same shaft.

In closing the discussion, Mr. Söderberg answered a question as to the practicality of balancing a centrifugal pump rotor that the problem could be solved by mathematical analysis. He pointed out that the difficulties of balancing were multiplied many times when working with small rotors.

After Mr. Söderberg's paper was presented, there was a symposium on the Machine Tool and the Pulp and Paper Industry. Six written discussions were presented with a foreword by George E. Williamson[30] who pointed out the probability that the interrelation of the machine-tool industry and the paper and pulp industry had not been given the detailed study which the subject warranted.

In the first three of this group of discussions, shop problems in paper-machinery manufacturing and the general requirements of the machine tools employed therefore were dealt with by E. T. Spidy,[31] Geo. S. Barton,[32] and H. L. Kutter.[33]

Mr. Spidy spoke of the shop problems involved in the building of the modern newsprint machine, approximately 300 ft. long 14 to 20 ft. wide, and containing 800 tons of metal, as well as the methods of scheduling to insure delivery in the six to seven months allowed for that purpose. He described, among other operations, the methods used in casting and machining driers 20 ft. long by 5 ft. in diameter; straightening, grinding, and balancing the various types of rolls; the securing of interchangeability; methods of erection, etc.

Mr. Barton pointed out that the paper-making machine was not a precision tool, and while many of its parts were often finely and accurately made, nevertheless the tolerances as to bearing sizes and other machined surfaces were far more liberal than was customary or even permissible in machine-tool construction. Every shop building paper machinery should be provided first of all with heavy-duty lathes capable of swinging parts 72 in. in diameter by 20 ft. long and weighing 15 to 20 tons. One of these lathes should be fitted with a boring bar.

Mr. Kutter stated that the general tool requirements of shops making paper-mill machinery were substantially those of establishments doing general heavy work in which no extensive standardization was possible. In addition to the heavy-duty lathes mentioned by Mr. Barton and the more common tools used in machine shops, he enumerated lathes for machining press rolls (32 in. swing by 25 ft. between centers); special machinery for grinding press rolls; a 300-ton hydraulic press for forcing bronze jackets over press rolls; lathes for machining felt and paper-carrying rolls made of pipe or steel tubes (24 in. swing by 23 ft. between centers); a hydraulic machine for straightening these tubes or pipes; planers up to 84 in. wide, and boring mills taking work up to 10 ft. in diameter.

Jas. A. Cameron[34] discussed the plant equipment necessary for producing paper-working machinery. In this class were included paper-coating machines, slitting and roll-winding machines, printing machinery, machines and appliances for making boxes, envelopes, bags, etc. Such machines were built in so great a range of types and sizes for specific requirements that there was no such thing as standardized shop facilities in connection with their manufacture. A web press might accommodate a web 12 in. or less wide for tickets, or more than 6 ft. wide for magazines. Boxes, bags, envelopes, tubes, etc., varied so much in size, kind, and style that shops building the machinery to make any of these products must be equipped for all-round work.

Edward Hutchins[35] and E. B. Wardle[36] dealt with the requirements of pulp- and paper-mill repair shops. Mr. Hutchins called attention to the fact that practically all repair work not caused by actual breakdown of machinery must be done on Sundays and holidays. The paper-mill repair man had to be an all-round mechanic who had great pride in his ability to do a good, rugged piece of repair work with makeshift tools and materials when such work was necessary to keep the plant in operation. The equipment of the repair shop must be suited for work on large and heavy machine parts and must be reliable, simple, and easy to run. On account of Sunday and holiday operation of the tools motor drives were to be preferred.

Mr. Wardle stated that as pulp and paper mills ran continuously on a schedule of six days per week, it was essential to minimize loss of production by making repair parts in advance when the need for them could be foreseen, and by installing necessary equipment to make quick repairs in emergencies. Mills making paper and pulp were naturally located where the supply of wood and power was most plentiful and suitable. This generally meant that the location was more or less remote from centers where facilities were available for repair work, and such mills must therefore be equipped with tools to handle anything up to rolls weighing 25 tons and 25 ft. in length. Both Mr. Wardle and Mr. Hutchins gave lists of the various machines that should be included in the equipment of such repair shops.

An understanding of the far-reaching importance of the work of the Machine-Shop Practice Division in American industry was convincingly demonstrated in the report of the Special Committee on Plan and Scope, which presented its report at this session.

The Committee recommended that the activities of the A.S.M.E. in the field of machine-shop practice be as follows: (*a*) To promote the art of machine-shop practice; (*b*) To encourage original research in the machine-shop field; (*c*) To foster education in machine-shop practice, and to persuade educational institutions to increase their attention to this subject; (*d*) To advance the standards of machine-shop practice, and its exact knowledge; (*e*) To promote the intercourse of those engaged in machine-shop practice among themselves and with the other members of the Society, and with other societies. To carry out these activities the Committee recommended an organization of sub-committees and outlined their relation with the present Executive Committee. To understand the broad scope of the plan, attention is called to the fact that the Division intends to search out for papers, information of a fundamental and research nature applicable to all machine shops. As such papers cannot be obtained on the spur of the moment or even on several months' notice, the new Snb-Committee on Planning is charged with the responsibility of laying down a ten-year plan under which the various shop processes can be taken up. By laying plans thus far ahead, it will be possible to keep in touch with the experimental work of various kinds, and when its development is sufficiently advanced, arrange to have it presented before the Society. The Committee also analyzed the various products that might well be considered in the field of the Machine-Shop Practice Division and the various processes employed in their manufacture.

The Committee on Plan and Scope consists of K. H. Condit, Chairman, A. L. De Leeuw, Erik Oberg, Earle Buckingham, J. J. Reynolds, Frederick Franz, and W. J. Peets.

General Session

THE ONLY General Session of the Meeting was held on Thursday morning, May 31, with Earl F. Scott, member of the Council, acting as presiding officer. A paper on the Control of Civil Aviation in Canada was presented through the Aeronautic Division by J. A. Wilson[37] Secretary of the Canadian Air Board. Mr. Wilson's paper, which will appear in a later issue of Mechanical Engineering, treats of international flying regulations and the rules in force in Canada for the development of safe flying. The subject of Endurance Data and Its Interpretation was treated by K. Heindlhofer[38] and H. Sjövall.[39] Their paper will appear in a later issue of Mechanical Engineering, as will the paper on the Bending Stresses in Curved Tubes of Rectangular Cross-

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[33] Secy., The Black-Clawson Co., Hamilton, Ohio. Mem. A.S.M.E.

[34] Pres., Cameron Machine Co., Brooklyn, N. Y.

[35] International Paper Co., New York, N. Y.

[36] Ch. Engr., Laurentide Co., Ltd., Grand Mere, P. Q., Canada.

[37] Secy., Royal Canadian Air Force, Ottawa, Canada.

[38] Research Eng., SKF Industries, Philadelphia, Pa. Mem. A.S.M.E.

[39] Research Engr., SKF Industries, Philadelphia, Pa.

Section by S. Timoshenko[40] which was presented at this session by title.

Public Hearings and Committee Meetings

FRED R. LOW, Chairman of the Main Committee on Power Test Codes, presided at the Public Hearing on Tuesday, May 28, at which the Codes on Internal-Combustion Engines and two chapters of the Code on Instruments and Apparatus were presented. A number of suggestions were received and referred to the Sub-Committees interested for their guidance in completing the codes.

In connection with the recent revision work on the Boiler Code, sufficient progress has been made by the Sub-Committee on Rules for the Care of Power Boilers and on Rules for Inspection of Materials and Boilers, so that their preliminary reports were submitted to Public Hearing at the Spring Meeting. The hearing on the Proposed Rules for the Care of Power Boilers was on Tuesday, May 29, while the hearing on the Proposed Rules for Inspection of Materials for Boilers was held on Wednesday, May 30. Both hearings were well attended and developed valuable suggestions in regard to the proposed new sections of the code.

The results of years of effort on the part of the Research Sub-Committee on Fluid Meters, were presented in a report at an open meeting on Thursday, May 31, for discussion and comment. The report is in the form of a reference book on flow meters of all kinds and is in two parts. Part I treats the general types of meters as well as the principles and methods involved and gives information which may in many cases be applicable to various commercial meters. Part II gives more detailed information concerning the practical use of all the flow meters now in common use. The discussion at the open meeting brought out a great many valuable suggestions that will be followed by the committee in the completion of its report. The work will be brought up for further public consideration at the Annual Meeting of the Society in December.

On Thursday, May 31, the regular May meeting of the A.S.M.E. Boiler Code Committee was held, at which there were present, in addition to a splendid representation of the Committee members, inspectors from the Canadian provinces and boiler manufacturers and engineers from distant points who are interested in the Committee's activities. The program of this meeting involved the usual interpretation work and a number of official communications in regard to boiler-construction matter.

Hydroelectric Possibilities of Quebec

(*Continued from page 409*)

b Troubles occurring in the water channels above or below the power house affecting the head acting on the turbine.

To a large extent the troubles in classification (*a*) have been overcome by better design of the power house and better knowledge of the cause of these troubles. By enclosing the rack structure and by getting the turbine chambers warm and in general by the use of larger units, much of the trouble which was experienced formerly has vanished. The other trouble is more difficult to remedy, and inasmuch as the change of levels may be due to blockades of considerable area, the remedy in most cases is peculiar to the power development.

Most plants on the St. Lawrence River experience variations in height of headwater or tailwater due to ice blockades at long distances from the power house. On smaller streams, and particularly on very small streams, these blockades may be extremely serious, as they may and do affect a large portion of the flow of the river.

In large power developments, ways and means have been developed which minimize to a considerable extent these difficulties, and the expense of carrying out such efforts is justified in case of large plants where it would not be in small ones. By keeping the channels open to permit the frazil ice to come up to the surface, and by the use of various skimming devices for keeping rid of this ice, a very considerable degree of success has been obtained at the Cedars Rapids plant on the St. Lawrence River. It may fairly be stated that while this ice difficulty was a serious menace some years ago, now such is not the case, provided the plant is a large one and has been located and built with the knowledge acquired from the operation of existing installations.

The growth of hydraulic and hydroelectric development has been rapid and continuous over the past twenty years. The yearly rate of increase has been about seven per cent of the installed capacity per year over the last fifteen years, and the present total development is 1,070,000 hp. of hydraulic and electrical capacity combined.

At the present rate of increase the total available amount of hydraulic power, which is estimated at 5.25 million kilowatts or about seven million horsepower, will be developed and utilized in the next twenty-nine years. However, as the increase in development will in general follow the increase in population, it will take considerably less than twenty-nine years to develop all the power now in sight, and a careful study indicates that in twenty to twenty-five years the 7,000,000 hp. will be used up. Further, this time might be materially shortened if any large amount of power were exported from Canada.

Feedwater Heating and Plant Economy

(*Continued from page 420*)

from the house turbine is much less efficient than by bleeding the main unit, there being an advantage of approximately 1.85 per cent in favor of bleeding the main unit. This has led to a change in the type of house turbine installed. The tendency seems to be to carry only as much load on the house turbine as is necessary for the sake of reliability, paralleling the house turbine with the main unit and carrying all the load on the main unit, the switch being so arranged that in case of a heavy overload on the system, the house turbine with certain auxiliaries will pull away from the main unit and the house turbine will carry these auxiliaries at a slightly lower frequency until such time as the load can be again picked up by the main unit. The latest proposition is to carry no load on the house turbine but have it running so as to be able to pick up the necessary auxiliaries in case of trouble to the main unit. With this latter arrangement it is proposed to run a small pipe from the exhaust end of the house turbine to the condenser of the main unit, a check valve being placed in the main exhaust pipe from the main unit, maintaining in this way a rarefied medium for the rotor to spin in, so that it will not overheat when running idle. The vacuum required in the exhaust end of the house turbine to prevent overheating varies with the design of the house turbine. It is only with the most efficient types of turbine that there is any danger that the vacuum which it is possible to maintain in the exhaust end of the house turbine will not be high enough during the warm summer months. The losses of such a stand-by house turbine when running in a high vacuum are very small.

It is possible to heat the condensate about 13 deg. by using the condensate to cool the air in a closed generator-cooling system; and a rise of 7 deg. more may be obtained by absorbing the heat in the transformer and turbine oil. The use of condensate in these cooling coils will keep them clean; but there is some slight complication in regard to the operation of such a system during the warm summer months, or in case of dropping of load by the main unit. This latter is probably only important in case the transformers and turbine are not paralleled as a unit on the high side of the transformers but paralleled with the other units on the low side. These transformers will stand an interruption in the cooling-water supply for several minutes without injurious effect. In studying such a system and comparing the reduction in heat requirements, consideration must be given to the fact that by absorbing this waste heat the amount of steam which can be bled from the main unit is reduced; and while there is a possible reduction in the heat requirements of the plant of $1^3/_4$ per cent by absorbing the waste heat, if additional steam is bled from the thirteenth stage of the main unit the heat requirements will be about 136 B.t.u. per net kw-hr. higher than if the condensate temperature is raised by the waste heat in the generator air and transformer and turbine oil or the net gain in station economy of absorbing this waste heat is about eight-tenths of one per cent.

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SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

Recent Developments in Steam-Turbine Design

Largest Single-Cylinder Single-Flow Reaction Turbine Yet Built

DESCRIPTION of a turbine built by the Westinghouse Company in which large capacity at moderate peripheral speeds and conservative stresses have been made possible by the use of the Baumann system of blading, while a symmetrically expanding steam path eliminates eddies. Certain constructional features are also described.

The great problem in a large turbine is to provide enough large blades at the exhaust end to pass steam efficiently, while centrifugal

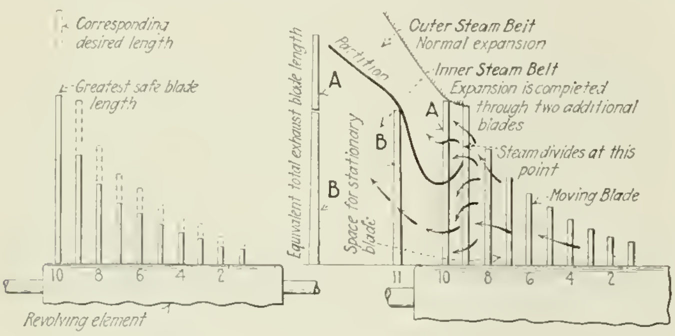

Fig. 1 Fig. 2

Figs. 1 and 2 Baumann Principle Increases Capacity of Single-Flow Turbine

force limits the blade length and diameters to those which will not exceed safe stresses in the materials available.

Designers have hit upon two ways for providing vane area for the complete expansion of the increased volume of the steam and its discharge to the condenser at a moderate velocity. One school has adhered to the single-cylinder direct-flow type, meeting the necessarily high peripheral velocities by refinements in material, design, and workmanship combined with a reduced factor of safety. Another school has attacked the problem by dividing the exhaust and providing two sets of exhaust blading, one at each end of the cylinder, making what is called the double-flow type; or by dividing the turbine into several turbine-generator units, with a high-speed, high-pressure unit exhausting into one or two lower-speed, low-pressure units. In the latter "cross-compound" type, high speed in the high-pressure unit is made possible by the relatively small high-pressure blades. This means that more work can be obtained efficiently per row of blades, since the work done per blade is approximately proportional to the square of the blade speed, and therefore less blade area is required. The slower low-pressure units are better for the employment of long vanes at the exhaust on account of lower centrifugal force at the required blade speed, and the double-flow principle is easily applied. The cross-compound unit possesses additional advantages of flexibility and reliability, but involves considerably greater first cost. Both of these expedients involve some disadvantages.

For the turbine described here, which is a 35,000-kw. unit under construction by the Westinghouse Co. for the Springdale Station of the West Penn Power Co., a method devised by Karl Baumann, of England, has been adopted.

Suppose that the largest single-flow reaction turbine, as limited by the safe length of the last row of blades, under ordinary design conditions carried 10,000 kw. at the most economical load and it is desired to increase this to 15,000 kw. at practically the same economy.

The high-pressure blades can easily be made longer so as to pass the greater volume of steam at about the same velocity, but the last row of low-pressure vanes is already of greatest safe length and cannot be extended.

Fig. 1 shows schematically such a reaction turbine, the blades in solid lines representing those for the largest single-flow machine of the usual design and dotted extensions suggesting added length for increased capacity, the proportions being only approximate. The last blade, row 10, is already of the greatest safe length and cannot be extended to A when the capacity is increased.

To pass the additional steam volume through the existing blade area in row 10 would mean increased steam velocity. Steam would then be discharged into the condenser at a high rate of speed, representing insufficient expansion and therefore lost energy that should have been used in driving the rotor.

The Baumann method of obtaining sufficient exhaust-blade area is illustrated in Fig. 2, where steam is divided into two belts at the last blade rows by means of partitions in the blades. The outer path allows expansion through ample blade area so as to do work efficiently.

Steam of the inner path is bypassed through rows 10, expanding only a small amount and doing little work. The expansion of this steam, however, is completed by adding a row of stationary and moving blades, rows 11, which contain sufficient area to use the remaining available energy efficiently and discharge into the condenser with the least practical amount of velocity remaining.

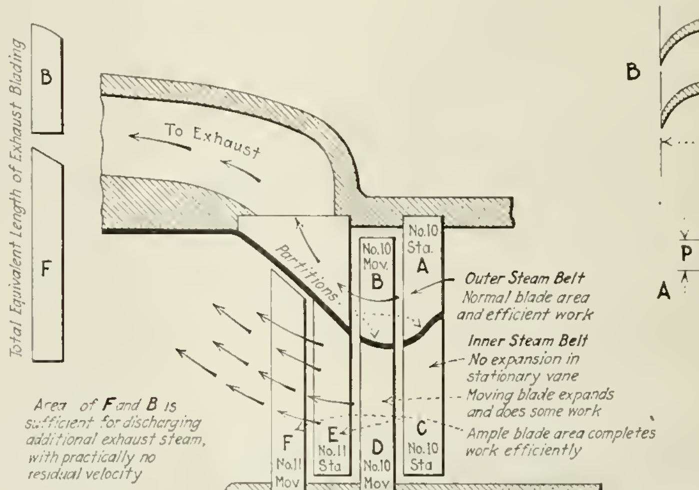

Fig. 3

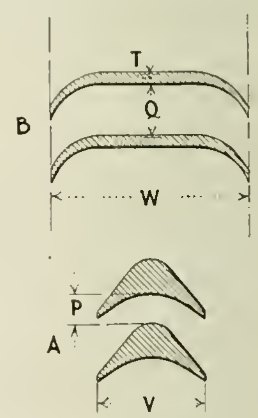

Fig. 4

Figs. 3 and 4 Inner Belt Does Less Work per Blade

The combined length of exhaust blades A and B is sufficient to give the desired total exhaust-blade area without an increase in blade length.

Fig. 3 shows in more detail the construction of rows 10 of blades, as well as added rows 11. The outer belt expands normally and efficiently through sections A and B.

The inner belt separated by partitions from the outer, is bypassed

through C stationary row 10 with practically no expansion; this section acts merely as a port. Moving section D expands steam to some extent, which helps drive the reaction vanes of the rotor.

There is still a comparatively great amount of energy remaining in the steam, and this is efficiently used by adding two rows of blades, E stationary and F revolving, which are proportioned for expansion to condenser pressure with ample exhaust area. By adding one row each of revolving and stationary blades, the capacity will be increased 60 per cent above the original. In adding two rows of each type of vanes and arranging an additional steam belt the increase is 120 per cent, and with three additional rows, 170 per cent.

Another means of increasing blade area due to Baumann is by greatly enlarging the blade width at the rotor, as shown in Fig. 4. Long blades must have a comparatively heavy cross-section at the rotor, as shown at A, which limits the width of the steam passage P between blades. The same cross-sectional area used in the blades at B with greater width W, permits thinner structure and consequently a wider steam passage Q between blades. Three steam passages to exhaust are provided in the 35,000-kw. units for Springdale.

In the original article the whole blading of the turbine is shown, the Baumann construction beginning only at a certain point toward the low-pressure side. The actual conditions are such that expansion takes place in the last moving vane so that it operates on the reaction principle.

Steam enters the first blade ring at 120 lb. abs., assuming that the most economical load, 26,000 kw., is being carried. The blade rings, instead of being supported loosely in rectangular grooves in the casing, are keyed into position, so that any tendency to close in on the rotor due to abnormal conditions is restrained by the resistance of the outer cylinder.

The rotor is of forged steel and a pressed fit reinforced by bolts unites the high-pressure with the low-pressure end. To make the rotor adaptable to high temperature the joint is located where there is very little difference of temperature, and the higher temperature if any is effective on the interior member of this pressed fit which would tend to hold it tight in case it became warmer than the recessed member of the fit.

The form of rotating and stationary packing employed is described and illustrated in the original article. In this the rotating element is finished in a number of conical surfaces, while the stationary member contains thin brass annular rings or fins which project very close to the rotating body. Clearances are adjusted by moving the rotating body in an axial direction. If rubbing should occur the conical elements will radiate heat much more rapidly than the old type of ring of cylindrical shape, and there is less liability of stripping than would occur in case thin fins were used in both the moving and stationary elements.

Numerous other features are described in the original article. Of these may be mentioned the emergency governor, which, in accordance with the recent tendencies in design, is of a type that will reset itself automatically while the turbine is running, thus avoiding the excessive slowing down for resetting that was necessary with the older type. In this case the governor includes means for checking approximately whether it operates at the correct speed.

The guaranteed steam consumption of this unit at 300 lb. 650 deg. fahr. steam at the throttle, with a vacuum of 29 in. of mercury, is as follows:

Load, kw.	1,750	26,250	35,000
Lb. per kw-hr.	10.30	9.75	10.15

At the most economical load of 26,000 kw. the following amounts of steam are to be extracted:

High-temperature heater, 12.9 lb. sq. in. abs.: 16,380 lb. per hour.

Low-temperature heater, 3.20 lb. sq. in. abs.: 12,910 lb. per hour. (*Power*, vol. 57, no. 20, May 15, 1923, pp. 746–752, 14 figs., *dA*)

5000-Kw. Brush-Ljungström Steam Turbine

THE first public description of the Ljungström steam turbine appeared in *Engineering* of April 12, 1912. Since then it has been successfully introduced in many places. As is well known, the particular feature of this turbine is that the fixed casing and single rotor of an ordinary turbine are replaced by two rotors turning in opposite directions.

The original 1000-kw. unit was soon followed by larger units until the size of 5000 to 7000-kw. was reached in 1916. These turbines were designed, however, to work with a vacuum not exceeding 28 in., and when with the development of condensing apparatus a vacuum of 29.1 in. was commercially reached, the Ljungström turbine had to encounter the same difficulty as all other turbines, namely, producing a steam path sufficiently ample to reduce "leaving losses" to a reasonable percentage. In the Ljungström turbine this problem was solved by fitting radial blades to the periphery of the Ljungström rotors.

The essential features of the construction of the turbine may be seen from Fig. 5 showing the upper half. The two steam rotors are denoted by h and h^1, respectively. The steam enters between the rotors near the center and flows radially to their circumference passing through the blading shown. This blading was described in detail in a previous article, as also the methods used in its manufacture, so it is not necessary to refer to it more particularly here.

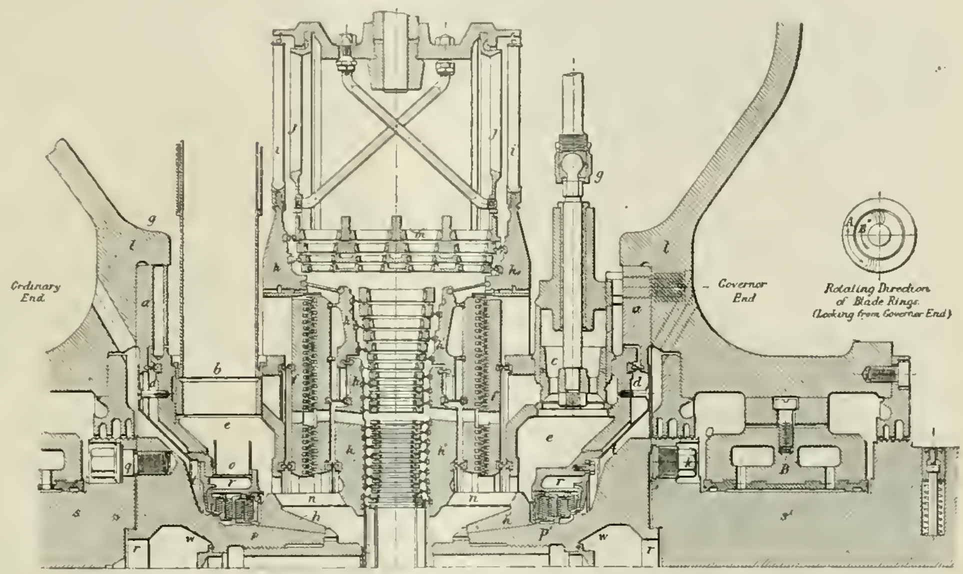

Fig. 5 Section through the Upper Half of the Brush-Ljungstrom Steam Turbine Showing the Direction of Rotation and Blade Rings

The original Ljungström turbine terminated in the row of blades lettered m, but with the high vacuums now specified it was impracticable to make such blading long enough to provide the requisite steam way. Hence, in the new model, after leaving m, the steam is passed through the fixed guide blades j, which direct it on to impulse blading i, which is, it will be seen, mounted radially on the periphery of the rotors. This last stage of the turbine provides, it will be seen, a "double flow," giving an ample steam way and moderate "leaving losses," the axial velocity of the steam on leaving the last row of blades being from 500 to 550 ft. per sec. The steam chest e is machined out of a solid steel forging and is carried from the flanges a, a by means of the dumb-bell expansion rings shown at d,d. These enable the components to adjust themselves, without heavy strain to changes of temperature. Similar dumb-bell rings connect to the steam chests e,e, the stationery labyrinth disks f,f, which form one-half of the dummies which prevent serious leakage from the steam chest to the exhaust space g. These dummies were fully described in previous articles, to which reference has already been made.

Each of the rotors h and h^1 is built up of three main components exclusive of the labyrinth disks. These three sections are also connected to each other by dumb-bell expansion rings. The innermost section of each rotor fits on to a conical seat p or p^1,

which can be bolted to the corresponding generator shaft s or s^1 by a ring of bolts one of which is shown to the left at q.

At the corresponding position on the opposite side of Fig. 5 is shown a starting bolt k which, when the turbine is to be dismantled, is used to bring out of their recesses the registers at r or r^1. In effecting this operation, the rotor of one of the generators is displaced for a short distance axially. The flanges a,a are, of course, free once the top cover has been removed, and once the registers are clear, the whole of the turbine can be lifted out of place as the steam-pipe joints are merely telescopic. Special tackle is provided for this operation which will be discussed later.

Steam from the steam chest c gets access to the blading through a series of openings n,n machined in the innermost sections of the rotors. In passing between the rotors, the steam produces a heavy axial thrust on each, and this thrust is balanced by the counter pressure of the steam which is simultaneously leaking through the dummies f. Any residual thrust is carried by Michell thrust bearings. As originally constructed, oil-filled dashpots were provided for this purpose, but while quite effective, they required careful attention to prevent leakage of oil or the entrance of air.

The glands w,w, where the rotor shafts pass through the fixed steam chest, have to be packed against high pressures. The escaping steam, as it leaves the last constriction of the gland, is caused to draw in air, by an ejector action, from the spaces t,t; and to discharge it into the spaces r,r, which are connected by pipes, one of which is indicated at o. This pipe leads away the mixture of steam and air to a separate condenser. The object of this arrangement is to prevent the possibility of steam leaking into the space t, where it might condense and fall into the oil, while further steam might pass beyond the bearings to the generator windings.

Owing to the gland steam being thus diluted with a large admixture of air, it cannot be turned into the main condenser, and a small auxiliary condenser has to be provided accordingly. The main condensate from the turbine passes through the tubes of this condenser, thus recovering the heat from the gland steam. Repeated measurements have shown that this gland leakage amounts to from $^3/_4$ per cent to 1 per cent of the total steam passing through the blades.

The turbine is governed by throttling the supply to a small servo-motor arranged above the steam stop valve. The piston of this motor is spring-loaded, and the stop and governor valves are opened by forcing oil below this piston so as to raise it against the pressure of the spring. The valve opening depends upon the height to which the piston is raised, and this depends, in its turn, on the pressure of the oil admitted below it.

A noticeable point in this governor is that no dashpot is provided to stop hunting, as it has been found unnecessary if friction be adequately eliminated. To this end ball bearings have been freely employed and very ample and complete lubrication provided for. The builders state that this is so effective that in certain cases the rise in speed between full load and no load has been under 1 per cent. In addition to this, emergency governors described in the original article are fitted into the generator shafts.

The original article also describes the many interesting details of the installation, such as the construction of the main bearings, details of the Michell thrust bearings, overload valve, steam glands, oil cooler, the special tackle used for lifting the turbine in and out of place, and the air pump—which is really a Brush-Delas ejector, as well as the generator driven by the turbine. No data of tests are presented. (*Engineering*, vol. 115, no. 2992 and 2993, May 4 and 11, 1923, pp. 542–545 and 577–578 and 2 plates of drawings, illustrated, dA)

Hardness and Hardness Testing

The Quality of Hardness

To FIND OUT exactly what hardness is and to state its measure in the fundamental units is a work of pure science which no one seems yet to have attempted. The first step in the process is for some physicist with insight, a type of man which this country fortunately produces fairly frequently, to frame a hypothesis based on what is known of molecular physics, and consistent with the various phenomena of hardness. The confirmation of the theory, by experimental verification of the conclusions which logically follow it, is a matter for the commonplace type of careful research worker, and can be carried out in any physical laboratory provided with the necessary equipment. The absence of any theory of what constitutes hardness is significant of the complexity of the characteristic of materials which is denoted by the term. The hardness of ivory is different from the hardness of lead, and this again is different from that of india rubber, yet any definition of hardness which is to be as scientifically precise as that of temperature, density, or elasticity, for example, must be applicable equally to all substances.

Several ways of testing hardness depending on different variables have been devised. If all these tests are true measures of hardness, it follows logically that there must be some consistent relationship between them so that their indications are convertible into the same scale of hardness. A vast amount of labor has been expended in the endeavor to establish mutual relationships between many of them, but with little real success.

Special attention is called to the scratch test described in a paper presented to the Institution of Mechanical Engineers recently. This test, like others, will no doubt have its uses in a particular field, but the field is likely to be a very limited one. Even if diamonds ground to standard angles could be commercially obtained, and a reliable scratching instrument could be devised, the measurement of the width of the scratches to the accuracy required by means of a high-power microscope is not for the ordinary workshop.

Exactly what property of the material the scratch test measures is by no means clear, but this is a defect common to all the other hardness tests. It has nothing in common with the old mineralogical hardness test which graded a material according to whether it would scratch or be scratched by any member of a series of standard materials. The point of a diamond will, of course, scratch anything, so that there is nothing comparative about the diamond scratch test except the size of the scratches a standard diamond will make under standard conditions. The first diamond point used in the experiments at the National Physical Laboratory was something like a blunt inverted pyramid, and, as might have been expected, the scratches were too ragged for accurate measurement to be made. They were, indeed, real scratches in the ordinary sense of the word. The next diamond tried was shaped something like a screw-cutting tool for cutting brass, but, again, as might have been foreseen, its action was to cut rather than to scratch the metal, and it "dug in" and cut wider and wider, exactly as a lathe tool would do under similar conditions. Finally, the diamond was reversed and the metal was dragged under it in the reverse direction, and under these conditions V-shaped grooves were pressed in the test piece. It is the widths of these grooves, which are of microscopic dimensions, which it was the object of the research to correlate with the hardness of the material.

Until our physicists have come to some agreement as to what property of the molecules of a substance, or what configuration of these molecules gives the quality to a material which we connote by hardness, the subject will never be put on a really scientific basis. There are enough and to spare of so-called "hardness tests," and nothing is to be gained by devising any more. If a certain Brinell number, scleroscope number, or scratch width is found to be associated with the quality of material which is satisfactory for a certain purpose, then the particular number or width can be used as an acceptance test for the material. This, in fact, is what is done in practice, and further than this the engineer cannot go at present. In spite of all the efforts which have been made to justify the several tests by scientific considerations they still remain empirical determinations of an unknown quantity. If hardness is wanted in a material for the resistance of abrasion, the amount of abrasion produced under given conditions is the only true measure of the kind of hardness required. If penetration is to be resisted, as in the case of armor plate, some kind of penetra-

tion or indentation test is obviously suggested. If, on the other hand, hardness is taken as an indication of tensile strength, or of chemical composition, it is surely better, whenever possible, to determine these characteristics directly. The ease by which certain so-called tests of hardness can be applied to finished material without injuring it, and the pseudo-quantitative nature of the numerical results obtained, tend, by reason of their attractiveness, to disguise the fact that it is an unknown quantity which is being measured, and one which may, or may not, be correlated with the characteristics desired.

The conclusion to which the author arrives is that the accumulation of the results of hardness tests of numerous kinds is now so vast that it seems that the time has come for the physicist to step in, and that the invention of further hardness tests and the collection of additional uncorrelated data are to be deprecated until some agreement can be arrived at as to the exact property of the tested material which is in question. (Editorial in *Engineering*, vol. 115, no. 2991, Apr. 27, 1923, pp. 527–528, *gA*)

Relation Between Width of Scratch and Load on Diamond in the Scratch Hardness Tests

By G. A. Hankins

Experiments described in the present paper have been carried out by the National Physical Laboratory for the Hardness Tests Research Committee of the Institution. The work was suggested originally by Dr. Unwin, who considered that the relation between the width of the scratch and the hardness number required further investigation.

The apparatus used for the tests is described. Of particular interest is the description of the various types of diamonds used for the test, as the type employed appears to affect the results to quite a material extent.

The results obtained show that with the materials used a straight-line law exists between the square of the width of the scratch and the load on the diamond, and that with each diamond under constant conditions the straight lines appear to meet at the same point for all materials. Taking p and q as the coördinates of this point, it appears that a law exists of the form:

$$(P-p) = k(w^2-q)$$

where P = load on diamond, w = width of scratch, and k = a constant for each material. Hence

$$k = \frac{P-p}{w^2-q}$$

k will thus be a stress, and it is suggested that the values of k for different materials may be taken as a measure for the hardness of the materials as determined by the scratch method.

Scratch hardness as thus defined has been plotted against the apparent Brinell hardness. The actual values of k appear to be dependent on the shape of the diamond and the angle with the test surface, but the type of curve is the same in all cases. The ratios of the scratch hardness to the Brinell hardness numbers have been calculated and are given in a table in the original article, from which it appears that a minimum value occurs at a Brinell hardness of about 450. With the exception of the value for copper, a progressive increase in the ratio occurs for both higher and lower values of the Brinell numbers. The manner in which the diamond has been used in the present tests appears to give a scratch which is of the nature of an indentation test on the materials, and therefore agreement with the Brinell numbers might be expected. The variations in the ratios seem too uniform to be due to experimental errors, and it appears that the test does measure a property of the material slightly different from that measured by the Brinell test. The value of the ratio found for copper is interesting when considered in connection with Professor Turner's statement, that "a piece of hard-rolled copper may give a greater hardness number than one of mild steel, yet a tool made of mild steel will always cut copper and no amount of cold rolling will make copper cut steel."

The results show that the method can be utilized to obtain a measure of the hardness of metals on the same scale over a very wide range, but at present the most useful applications would appear to be in the case of the harder materials or where only small or valuable specimens are available. For general use it seems that a standard shape of diamond would have to be adopted, since the results obtained depend on the shape of the diamond, but comparison of the results obtained with two of the diamonds used appears to show that small variations in the angles of different diamonds do not have a large effect on the results obtained. (Paper read before The Institution of Mechanical Engineers, Apr. 20, 1923, abstracted through *Engineering*, vol. 115, no. 2991, Apr. 27, 1923, pp. 537–540, 17 figs., *el*)

Static Indentation Tests

By R. G. C. Batson

This paper contains the results of various investigations which have been carried out for, and reported to, the Hardness Tests Research Committee for the Institution of Mechanical Engineers during the years 1919–1922, with a view to elucidating various points in connection with the application of indentation test as a measure of the hardness of materials. The points considered are as follows: (1) Investigation of law of comparison for ball indentation tests; (2) a comparison of the ball and cone methods of test; and (3) the determination of the relative hardness of very hard steels by means of ball hardness tests, in which the permanent deformation of the ball is taken as a measure of the hardness of the material producing it.

Among other things, the author compares results obtained by the employment of the cone pressure test such as is used on the Continent with those obtained with the standard ball method. For this purpose a series of tests has been carried out on four materials to compare the hardness numbers obtained by using a 10-mm. diameter ball and a 90-deg. cone, when these numbers are in each case calculated from (1) the diameter of the impressions as obtained by a measuring microscope after the test, and (2) the depth of the impressions when the pressure has been removed, measured from the original surface of the materials.

From these tests it would appear that

1 The hardness numbers obtained with a 10-mm. ball and calculated from the diameters of the impressions are not independent of the load. This fact is well known and has been pointed out by many experimenters.

2 When the depth of the ball indentation (from the original surface) is used for calculating the hardness numbers, the numbers obtained are independent of the load within the range of these experiments. This fact was pointed out by R. P. Devries in 1911 (U. S. Bureau of Standards Technologic Paper No. 11).

3 With the cone test the experiments made for the purpose of the present paper appear to show an effect of the opposite kind from that described under conclusions (1) and (2) for the ball test. The hardness numbers calculated from the diameters of the impression (using the conical area of the impression as recommended by Ludwik) are approximately constant, and those obtained from the depth of the identation vary with the load.

4 It follows from conclusions (1), (2), and (3) that with varying loads the complete impressions with the ball test are dissimilar, and with the cone test are similar. It also follows that, when the part of the impression caused by the "ridge" is neglected, the impression under varying loads given by the ball test are similar and by the cone test are dissimilar.

5 The hardness numbers with a load of 3000 kg. show that, whereas for three of the materials the ratio is approximately the same, for manganese steel the cone test gives a much higher relative result than the ball test. For this reason it is not possible to give a definite ratio under these conditions between ball-test results and cone-test results for all materials.

It will be noticed that for the three materials and with the methods of calculation adopted, the ball test gives numbers which are from 8 per cent to 13 per cent higher than the cone-test numbers when using the diameter of the indentation, and 3 per cent to 9 per cent lower when using the depth of indentation from the original surface of the test piece. It was suggested that in order to obtain the same hardness number for both ball and cone tests, the hardness number should be taken as equal to

$$\frac{\text{Load}}{\text{projected area of indentation}} = \frac{L}{\pi d^2}$$

where L = load and d = diameter of the indentation. By adopting this method of calculation the cone hardness numbers would be 41.4 per cent higher and the ball hardness numbers less than 12 per cent higher (this depending on the diameter of the indentation) than those obtained by the method previously described. There would thus be a still greater difference between the cone- and ball-hardness test numbers if this method of calculation was used. (Paper read before the Institution of Mechanical Engineers, Apr. 20, 1923, abstracted through *Engineering*, vol. 115, no. 2991, Apr. 27, 1923, pp. 534–537, 10 figs., *et*)

Short Abstracts of the Month

AERONAUTICS

Cycle Engines for Light Planes. Description of the Bradshaw 500-cc. oil-cooled engine. The main feature of this engine is that with the exception of the cylinder heads it is cooled by the lubricating oil, which is in turn cooled by radiation from the walls of the crankcase, which is therefore made of particularly large proportions.

Owing to the fact that the oil is used for cooling as well as for lubrication, the lubrication arrangement is naturally somewhat unusual. Driven from the camshaft is a gear pump, which draws oil from the sump in the crankcase through a large gauze filter, and delivers it under pressure to the internally drilled crankshaft. By a special system of oil-release grooves the flow of oil through the crankshaft and from the big ends has been increased by 100 per cent, so as to give cooling as well as lubrication. From the big ends the oil is splashed on to the cylinder walls, the inside of the pistons, to the valve gear, etc., and it is claimed that the whole oiling system requires no attention.

The engine, which is a flat-twin, is rated to develop in the neighborhood of 11 b.hp. at 2500 to 3000 r.p.m. and for this power weighs approximately 70 lb. in full running order, or about 46 lb. without flywheel, magneto and carburetor. (*Flight*, vol. 15, no. 18/749, May 3, 1923, pp. 240–241, 3 figs., *d*)

Jet Propulsion for Aeroplanes

Jet Propulsion for Airplanes, Edgar Buckingham. Data of work undertaken at the Bureau of Standards on the request of the Engineering Division, Air Service, U. S. Army, and later submitted with their approval to the National Advisory Committee for Aeronautics.

The term "jet propulsion" as commonly understood implies the use of a small intense jet maintained by some other means than an airscrew. Thus, if air is compressed and mixed with fuel in a combustion chamber where the mixture burns at constant pressure, and the combustion products issue through a nozzle, the reaction of the jet constitutes the thrust.

Only the simple nozzle such as is used in steam turbines is considered in the present investigation, which did not cover in detail the possibility of improving the propulsive efficiency of the jet by any of the aspirator or ejector devices that have been proposed for increasing the momentum and thrust.

Data are now available for an approximate comparison of the performance of a jet propulsion device with that of the motor-driven airscrew.

The conclusions at which the author arrives are not in favor of propulsion by the reaction of a simple jet, which he claims cannot compete in any respect with airscrew propulsion at such flying speeds as are now in prospect.

While the relative fuel consumption and weight of machinery for the jet increases as the flying speed increases, still even at 250 m.p.h. the jet would take about four times as much fuel per thrust horsepower-hour as the airscrew, and the power plant would be heavier, much more complicated, and also more delicate.

To say nothing of the fuel-injection system, the combined compressor and engine would have about twice as many pistons, valves, and other moving parts as a simple engine, and the chances of breakdown and the difficulties of upkeep would be correspondingly increased.

There are, to be sure, a few obvious advantages in the jet scheme. The large, awkward, and fragile propeller would be eliminated, and only the nozzle and not the engine would have to be located with regard to the axis of thrust. Thus the design would be more flexible. The machine might also, if strong enough, be given brilliant maneuvering powers by utilizing the powerful steering effect of swinging the nozzle. On the other hand, a machine which had to start, if it could get off the ground at all, by emitting a jet of flame at 2500 deg. fahr. and a speed of one mile a second would hardly be a welcome visitor at flying fields.

The only hope of success lies in the use of thrust augmenters which are devices or arrangements that will increase the momentum of a jet already formed without increasing the fuel consumption needed for maintaining the jet or adding seriously to the weight. Devices of this sort have been proposed and the author discusses them qualitatively. These devices consist mainly in surrounding the jet after it has left the nozzle by a series of ring-shaped guides, of curved profile, after the manner of an ejector or aspirator. If these guides are properly designed, the pressure in the internal free space about the jet falls below atmospheric, air is drawn in, and before it comes into actual contact with the jet, it has already, in its passage through the curved ports between the guides, acquired a considerable component of velocity in the same direction as the jet. The idea seems to be that the shock loss will be reduced and kinetic energy saved; that the backward momentum of the entering air will be added to that already present in the jet so as to increase the thrust; and that the thrust horsepower of the whole combination will be augmented, without any modification of the part of the apparatus originally provided for maintaining the jet or any increase of fuel consumption.

It is hard to see just how this sort of process can be analyzed and referred to the elementary principles of mechanics and thermodynamics so as to permit of forming any definite quantitative opinion of its feasibility. There is no doubt that ejectors and aspirators built on this plant have been very useful and effective for certain purposes; but whether, in the application now in question, they would have the effect hoped for seems very problematical, and the present writer remains skeptical. (*National Advisory Committee for Aeronautics*, Report no. 159, 1923, 18 pp., 7 figs., *et*)

Gyroscopes in Aircraft Instruments—Gray Stabilizer

On the Application of the Gyroscope to the Solution of the "Vertical" Problem on Aircraft, Prof. James Gordon Gray and Capt. J. Gray. Description of various devices, chiefly those developed from research work carried out in the Natural Philosophy Institute of the University of Glasgow, where the first of the authors is Cargill Professor of Applied Physics. These devices relate to apparatus for finding, maintaining, and thus defining the true vertical and horizontal on aeroplanes and airships. The so-called "vertical" problem and with it the application of the gyroscope is of importance. Navigation must be made precise by the provision of gyroscopic sextants; photography from airplanes to be accurate must be carried out by means of special cameras stabilized so that the photographs are true vertical productions; bombing from airplanes must be rendered accurate by designing the bombsight as part of an accurate stabilizer, etc.

The article is very extensive and can be abstracted only very briefly. Among the interesting portions which cannot be abstracted is a discussion of the behavior of a gyroscopic pendulum when it is mounted on an airplane which moves in a curved path. The authors derive the equations determining such behavior. From this it would appear that if the spin of the gyroscope is clockwise as seen from above, and the airplane moves round in the counter-clockwise direction as also seen from above, there will be a growing deflection of the pivoted system with respect to the vertical. In general, they come to the conclusion that if the gyroscopic pendulum is to meet with success it must have a real periodic time of precessional motion or virtual periodic time in the presence of curvilinear motion on the part of the airplane which is upward

of one hour. This would make pendulums which have a periodic time in excess of only 4 min. useless, notwithstanding the fact that such pendulums have been highly endorsed.

Furthermore, under the conditions which prevail on aircraft, gyroscopic pendulums which depend for their action on gravity control and dashpots are of little or no use; under such conditions these devices leave the vertical quickly and return very slowly.

The gyroscopic pendulum of the type in which the erecting action depends on the existence of precessional motion, is subject to an error due to the rotation of the earth when supported on a steady platform at rest. But if it is carried on a moving vehicle, such as an airplane, the errors due to the motion of the vehicle are so large that it is unnecessary to consider those due to the earth's rotation.

From this the paper proceeds to the description of the Gray stabilizer. It consists of a gyroscopic system pivoted in the conventional manner and having the following properties. Should the pivoted system be inclined to the vertical during normal flight of the airplane or airship, a stabilizing couple is applied to the gyroscope and the device is restored to the vertical. The stabilizing couple is obtained by means of a special erecting device, and depends in no way on precession of the gyroscope in the ordinary sense of the term. During curved flight of the airplane the erecting device goes automatically out of action. Thus the pivoted system leaves the true vertical very slowly, if at all, in the presence of curved flight, and approaches it relatively quickly during normal flight.

The various designs of this stabilizer are described in great detail. Experiments carried out by means of the sun-shadow methods (described in the original article) are claimed to have shown that these stabilizers remain absolutely undisturbed by the pitching and rolling motions of an airplane.

The authors recommend using powerful gyroscopes for airplanes with their stabilizers, such as, for example, those having an angular momentum of 2000 in ft-lb-sec. units. This is the angular momentum possessed by a whirl of mass 20 lb., radius of gyration 3 in., when performing 250 r.p.s. Complete with its casing and bearings such a gyroscope would have a mass of about 25 lb. and the diameter of its casing would lie between 7 and 8 in. For use on board ships of war in connection with anti-aircraft devices, much larger gyroscopes are recommended such as those having an angular momentum upward of 5000 in. ft-lb-sec. units.

An interesting feature claimed for the Gray stabilizer is that it is free of error due to rotation of earth. (*Proceedings of the Royal Society of Edinburgh*, vol. 42, no. 3, pp. 257–317, 38 figs., *tdA*)

AIR MACHINERY (See also Aeronautics)

Surface Air Coolers

Physical Consideration and Design of Surface Air Coolers. A. R. Smith. This article forms a part of a series under the general title of Cooling of Turbine Generators and deals with the details of design of surface air coolers.

The size of tube now used is $^5/_8$ in. outside diameter, 18 B.W.G. wall, and made of either muntz metal or Admiralty brass. While larger tubes may be used, it would appear that they do not present any important advantages.

In order to give the maximum amount of cooling surface at the minimum expense, the tubes are wound with copper fins spaced seven to the inch and having an effective depth of $^1/_4$ in. The addition of fins increases the external radiating surface of the tube, which is the high-resistance side, over six times. The fins are shouldered and soldered to the tube so that the joint presents no resistance to the flow of heat. They are flat and smooth.

The tube sheets are made of rolled muntz metal, which gives a non-porous tube sheet, and this prevents water from seeping through into the air space.

Over each of the tube sheets are bolted by means of studs and nuts cast-iron water boxes, provided with a large inlet and outlet to reduce turbulence, which would tend to affect the distribution of water through the tubes. The coolers are arranged so that the tube sheets form a part of the air duct, which leaves the water boxes accessible so that the tubes can be inspected or cleaned with the least possible inconvenience.

The plan so far has been to maintain a minimum water velocity through the tubes which would be in excess of the critical velocity. The maximum water velocity naturally depends on the pumping head permissible. The number of water passes depends on the number of tubes in the cooler and on whether condensate or circulating water is used. Eventually, the number of water passes will probably become more or less standard because the conditions under which turbine generators operate are not very different. For the present, however, any number of water passes can be obtained to meet conditions.

The flow of water with respect to the flow of air is counter-current.

The resistance to the flow of air through the cooler is dependent on the air velocity and the depth of the cooler, the temperature of the air having only a slight effect on the drop in air pressure through the cooler. If a fixed amount of surface is so distributed that the air velocity is low, the depth of the cooler will naturally be reduced; but the same amount of surface can be so distributed that the depth is considerably greater, which will result in a higher air velocity. When an approximation of the amount of surface is made, it is obvious that it can be so arranged, provided there is sufficient space, to obtain almost any resistance that may be desired.

Resistance to the flow of air in large air ducts of moderate lengths is almost a negligible factor. Excessive pressure drops are the result of eddying and loss of velocity heads. In laying out any duct system, and especially those in connection with surface coolers, where all of the available pressure loss should be applied to the cooler, the ducts should be carefully designed and in many cases can be so designed that the duct loss can almost be neglected.

The loss of head or resistance to the flow of water is also a variable quantity, and there is considerable latitude in regulating the total pressure drop. A velocity in the tubes of not less than 2 ft. per sec. is desired so as to keep the flow above the critical velocity. If a velocity of 5 or 6 ft. per sec. is attempted, the number of water passes are increased and the friction head increases very rapidly.

Where the coolers utilize the condensate as a circulating medium, then a relatively high velocity, say, of 4 or $4^1/_2$ ft., is desirable when the turbine is operating at full load, so that at partial loads the velocity is more nearly normal. The total pressure drop in the cooler from the inlet to the outlet nozzle usually runs in the neighborhood of 20 ft.

In most cases the surface cooler presents a number of economical and operating advantages. To what extent these advantages may be capitalized depends of course upon local conditions. The common advantages are as follows:

1 If the air-duct system contains but a small volume of air, no fire extinguisher should be necessary because the oxygen will be rapidly consumed and the fire smothered without requiring the attention of an operator, or the operation of any dampers.

2 If the proper precautions are taken to prevent any material infiltration of air, the deposits in the machine or on the cooler should be insignificant. If a clean generator is maintained, the temperature rise of the winding above the incoming air temperature should not increase with age.

3 The volume of water required for cooling the air can be regulated because the flow of water is counter-current with respect to the flow of air. Where water is expensive it is therefore possible to economize on the quantity.

4 The pumping head or the amount of auxiliary power required is extremely low.

5 Where condensate can be employed either wholly or in part, for the cooling of a generator, some or all of the generator losses are returned to the system in the form of heat.

There may be arrangements adopted where the puncture of a tube might release water into the generator. Such a condition can be guarded against by the installation of water eliminators which have been developed especially for such a purpose. The employment of eliminators, however, will introduce additional friction in the air circuit and it is recommended that the coolers be so located as to avoid the necessity of using eliminators. With the cooler sections located below the generator the spouting velocities of the water may prevent it from entering the generator winding even though it is assumed that such a leak develop at just the right point on the upper row of tubes. (*General Electric Review*, vol. 26, no. 5, May, 1923, pp. 298–303, 5 figs., *d*)

ENGINEERING MATERIALS

New Bearing Metal—Thermit. Data of a new metal developed by Professor von Hanffstengel together with the Th. Goldschmidt Co. in Essen. The exact composition of the new metal is not given. It is stated, however, that it belongs to the class of materials containing lead, in addition to which it has other ingredients. Its properties depend essentially on correct alloying and mixing practice, and it is stated that it gives better results than certain other bearing metals used in machinery when it so happens that the bearings fail to receive proper lubrication. (*Technische Blaetter*, published weekly by the Deutsche Bergwerks-Zeitung, vol. 13, no. 16, Apr. 21, 1923, pp. 113-114, 4 figs., *d*)

Coronium Bronze Alloy. The precise composition and process of manufacture of the alloy is not given, but it is stated that it contains copper, 16 parts; zinc, 3 parts; and tin, 1 part, which figures include the usual impurities.

With regard to physical properties, in ordinary sand castings of handy size, tensile tests have given 16 to 18 tons per sq. in., according to conditions connected with each case. In some cases where very special castings have been made and unusual precautions taken in the pouring and cooling, an ultimate tensile test of 22 tons per sq. in. has been officially reported. In one of the cases last referred to, the elongation was officially given as 38 per cent on 2 in., this having reference to the same test piece, and at the same time there was a reduction of area observed of 37 per cent. The elastic ratio observed at the same time was 0.6, a figure of great importance. Referring again to the figure of from 16 to 18 tons per sq. in., engineers using the material for commercial purposes can safely rely upon an elongation taken on the same test piece having a figure in excess of 25 per cent in 2 in., with a reduction of area in excess of 25 per cent at the same time. The Brinell hardness as cast may be taken under any circumstances at a figure of 85 to 90 on the Brinell scale, and the machinability—assuming good brass to be 80—at 100.

The metal can be rolled cold into sheet of the finest gages, and drawn into rods or tubes and generally wrought with ease. The effect on the physical properties of rolling into rod is a good general example of the result of mechanical treatment, and the tests that have been made gave very interesting results. Test pieces were taken from a bar rolled from the ingot to $^5/_8$ in. in diameter, and the maximum tensile stress was proved to be over 35 tons per sq. in., with a corresponding elongation in 2 in. of 58 per cent and a reduction of area of just over 60 per cent. The specific gravity in the cast state is 8.9, as compared with 8.8 as the maximum figure obtained in the heaviest phosphor bronze as cast. The melting point is 1100 deg. cent. (2030 deg. fahr.). The strength and elastic limit are not seriously affected by annealing. Compared with phosphor bronze, the latent heat is greater, and the heat conductivity correspondingly rather less. The alloy has an electric resistance as great as that of nickel (whose resistance is materially higher than that of any copper alloy). The power of resistance to corrosion, so far as it has been possible to test the matter, seems to be very high. The coefficient of expansion has not been finally determined, but observations up to date show that it corresponds very closely to that of cast iron. (*Foundry Trade Journal*, vol. 27, no. 350, May 3, 1923, pp. 359, *d*)

Centrifugally Made Concrete Poles

Concrete Poles Made by Centrifugal Process. Reinforced-concrete poles made by centrifugal process are receiving considerable attention these days, particularly in Europe.

One of the largest power-transmission lines in Sweden is carried by means of such poles. These carry two cables between the poles, which are about 36 ft. apart, and two at the ends of the cross-beam, which is about 54 ft. in length. According to the changing local conditions along the line and the variations in the load from 1200 to 1400 lb., four different sizes of poles were made which were from 56 to 59 ft. in height, from 9 to 10 in. in diameter at the top, and from 18.5 to 23 in. at the bottom. The average wall thickness is 2 in. Nearly 6 per cent of them were tested, and some—about 1 per cent of the whole number—were subjected to bending stresses till fracture occurred.

It was stipulated that the latter had to withstand at least four times the highest ultimate load at the top. The others had to be subjected to double that load without showing any cracks or alterations of form. The tests proved, however, that the poles were exceedingly elastic and could carry six to eight times the highest ultimate top load. During the tests the load was taken off several times, and the top went almost completely back into its original position, showing that the bending was of an entirely elastic nature. Even after fracture had occurred the steel reinforcement was still able to stand considerable stress as it had only slightly been damaged. In some cases when the breaking stress had been reached, cracks from the tensile stress outside the bend and signs of excessive pressure inside the bend appeared at the same time, which shows that the tensile stress which centrifugal concrete will stand is considerably above the usual normal for concrete. Some of the poles, 64 ft. long, being subjected to a bending stress of 7300 lb. bent $7^1/_2$ ft. at the top without any signs of damage. The poles were tested at an age of six to seven weeks. It had also been proved that their earth connection, which was brought about by attaching contact pieces to the steel reinforcement, was good, and that the electric resistance was less than 0.2 ohm.

These poles are manufactured in a wooden mold which is revolved in a special machine. This mold consists of two half-round forms, and is lined with sheet iron inside. The reinforcement is formed by rolled rods, of open-hearth material, going lengthwise, which are interwoven with three spirals of wire one within the other. It is wound upon a special automatic machine, so that the uniformity in their measurements and the strength of the poles is insured. The spirals influence the fracture stress comparatively little but they determine to a certain extent the rigidity of the pole, and by using three spirals it has been possible to reduce the bending to 0.5 per cent of the length at the normal load, and to 1.5 per cent at the double load. In order to give the maximum strength to the pole, care is taken that the reinforcement comes as close as possible to the circumference and is at an equal distance away from it. The cement mortar is mixed in proportion of one to three, and some asbestos fiber is added to assist in holding the sand and cement together.

After the wire structure and the cement have been put into the mold, it is closed and put into the machine. According to the diameter of the pole, the mold is then revolved at a speed of 500 to 1000 r.p.m. This high velocity, which is attained immediately after starting, and continued revolution at the same speed are necessary to prevent a decomposition of the mortar, which would take place on account of the different specific gravities of sand and cement. The excessive water in the mortar accumulates in the hole in the center, and in striking the wall of the pole during the rotation, increases the compactness of the grain. The fears that the cement would be thrown to the outside and that the mixture would become less rich toward the center have been proved unfounded.

The centrifugal arrangement consists of several machines which are lined up one behind the other. Each machine has two strong side frames with a large center bore. Inserted in the bore is a tube which rolls freely between six wheels carried by three shafts which may be adjusted radially in relation to the bore. The tube is fitted with a self-centering chuck for holding the wooden mold. All machines are driven from a main shaft, the center tube serving as a pulley. After revolving the mold in the machines for about 10 to 15 min. it is taken out, the lid at the end is removed, and the water is poured out of the center. The pole is left in the mold for 1 or 2 days. It has then set sufficiently to be taken out, and is kept in moist sand for about 3 to 4 weeks. (*Power Plant Engineering*, vol. 27, no. 10, May 15, 1923, pp. 531–532, 2 figs., *d*)

HYDRAULICS

The 40,000-Kva. Shawinigan Falls Water-Wheel Generator, J. Ralph Johnson. Description of a generator installed in a Canadian plant and notable not only on account of its size but also for certain features of design of the most modern character. It has been in operation since October, 1922, and is a unit of the vertical type with direct-connected exciter designed to deliver normally 40,000 kva. of three-phase current at 0.75 power factor,

60 cycles, and 11,000 volts while running at a speed of 138.5 r.p.m. It is, however, capable of working at considerable overloads and overvoltages for limited periods of time.

Only the mechanical features of design will be primarily reported in this abstract, although the article contains also the description of several interesting electrical features.

In this installation the operating floor is level with the top of the stator frame. This construction gives ample space round the generator on the main floor and provides a convenient means for dealing with the exhaust air from the generator in the annular space beneath this floor. The air may either be utilized to heat the generator room in winter by opening up steel trap doors in the floor, or in the summer it may be ejected outdoors through the windows in the outer wall beneath the main floor.

The rotor spider is made of cast steel and consists of three wheels, each made up of two semicircular sections bolted together at the hub and linked together to the rim by shrink keys. The rim, arms, and hub of each section are cast solid. Some manufacturers have raised objection to this type of rotor construction in large units owing to the difficulty of obtaining reliable castings. If, however, proper care is taken in annealing, testing of samples, and keeping stresses at overspeed within half the elastic limit, entirely reliable castings can be and have been made. The shaft is made of forged steel and has a solid forged flange which is bolted to the water-wheel shaft flange for coupling. The coupling bolt holes were reamed on site, thus insuring proper alignment of the two shafts.

The total weight of the complete rotor is 201 tons and the flywheel effect is 35,034,000 lb-ft.[2] In view of the enormous kinetic energy stored in the rotating parts a mechanical braking system was installed to bring the machine from normal speed quickly to rest. This braking system also helps to hold the rotor at rest against possible leakage past the water-wheel gates when the Johnson valve is not closed. The braking system is described in some detail in the original article. An interesting feature of it is that the brakes may be used when necessary as jacks to raise the rotor from the thrust bearing for inspection or repair purposes.

The generator guide bearing is of the standard babbitted type and the water-wheel guide bearing is of the water-lubricated lignum vitae type. On the machine itself is used a spring thrust bearing consisting essentially of a spring-supported stationary babbitted plate and a highly polished hard, gray-cast-iron rotating plate. The stationary plate is supported on a large number of helical springs loosely pinned to a baseplate which is doweled to the machined face of the upper bearing bracket. The flexibility of this support allows the plate to conform to the natural alignment of the shaft, thus preventing excessive local pressures in the bearing and allowing the maintenance of an oil film between the bearing surfaces.

The bearing operates in an oil bath and the heat generated is taken up by the oil as it passes by centrifugal action between the bearing surfaces. Heat is also transmitted to the oil through the metal of the bearing plates. The heat is removed from the oil by the circulating water in a stack of cooling coils immersed in the oil bath. Clean oil is pumped from a filter tank on the ground floor to an upper tank above the level of the machine. From the latter tank the oil is piped to the guide and thrust bearings, thence to a common drain which returns to the filter tank. If by any chance the oil pumps (one of which is in reserve) have to be shut down, the generator may still run if the thrust-bearing oil-supply line is shut off, as the storage tank can supply the guide bearing for several hours and the cooling coils will maintain the oil in the thrust bearing at normal temperature. (*General Electric Review*, vol. 26, no. 5, May, 1923, pp. 263–268, 7 figs., *d*)

Flow of Water Through Pipe

The Flow of Water Through Vitrified-Clay and Corrugated-Metal Culvert Pipe. Results of an extensive investigation conducted by the U. S. Bureau of Public Roads at the State University of Iowa Hydraulic Laboratory. Among other things capacities of the two kinds of pipe are compared and values of coefficient of roughness in the Kutter formula have been determined.

The sizes tested of each kind of pipe were 12, 18, 24, and 30 in. in diameter, and to determine the effect of the length of the culvert on its capacity the 24-in. pipe of both materials was tested in three lengths, namely, 24, 30, and 36 ft. Many different types of entrances were tried, such as various conical entrances, straight end-wall entrances, wing walls set at 45 deg. to the pipe line, and the new-type wings. The effect of varying the height of the wing wall was also tested.

The testing equipment and procedure of testing are described and the experimental results given in the form of characteristic curves for the various types of pipe and a short table.

Piezometer readings were found to be quite inconsistent and more erratic in general with the vitrified-clay pipe than with the corrugated-metal pipe. The piezometer closest to the entrance end of every pipe invariably showed a reading below the average hydraulic gradient when the velocity was high.

Perhaps the most surprising thing about these diagrams is the striking way in which they reveal the fact that for such short pipe the element of friction in the pipe itself is much dwarfed in comparison with the head consumed at entrance in getting the water into the pipe. As shown in Fig. 1, the friction head for the 12-in.

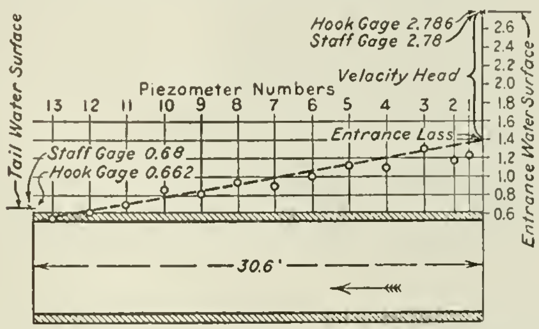

Fig. 1 12-in. Vitrified-Clay Pipe, 30 ft. Length, Straight End-Wall Entrance, Flat Slope

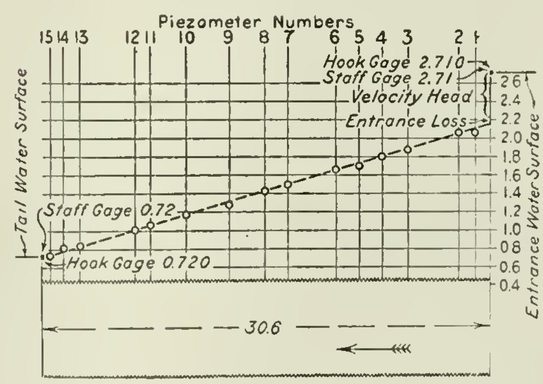

Fig. 2 12-in. Corrugated-Metal Pipe, 30 ft. Length, Straight End-Wall Entrance

clay pipe was much less than the velocity head consumed at entrance. This relation is independent of the velocity of flow, for as the velocity increases both the friction loss and the velocity head increase in substantially the same proportion. For pipe of larger diameters the frictiou loss has less importance.

With corrugated-metal pipe the friction factor is much greater than with clay pipe and is therefore of greater importance. Fig. 2 shows a 12-in. corrugated metal pipe carrying nearly the same quantity of water as is carried by the 12-in. clay pipe represented in Fig. 1. Although the velocity head is about the same in the two figures, the friction head in Fig. 2 is several times as great as in Fig. 1. The friction loss in vitrified-clay pipe and corrugated-metal pipe may be compared by calculating for each the coefficient of roughness by Kutter's formula. When this was done it was found that the results varied slightly with different sizes of pipe and different velocities of flow. For clay pipe the values obtained for Kutter's exponent n varied between 0.011 and 0.014; for corrugated-metal pipe between 0.019 and 0.024. The greater resistance to flow in the metal pipe is undoubtedly caused by the corrugations. (*Good Roads*, vol. 64, no. 14, Apr. 4, 1923, pp. 131–133, 2 figs., *e*)

INTERNAL-COMBUSTION ENGINEERING (See Aeronautics; Special Machinery)

MACHINE TOOLS (See Special Machinery)

MARINE ENGINEERING

Water-Tube Boilers in Marine Service

Operation of Water-Tube Boilers in Passenger and Cargo Ships, R. Clark. A paper of largely practical character discussing the operation of three types of boilers, namely, Babcock & Wilcox, Yarrow, and Stirling, along with various automatic controls required in their operation. The author has mainly in view the Class H standard ships. These ships have a carrying capacity of 3800 to 4000 tons and are driven by triple-expansion engines.

Among other things, the author mentions that a considerable time ago, owing to certain troubles developing in cylindrical boilers, the Admiralty Boiler Committee made investigations, and it was shown that the limit to which cylindrical boilers could be worked represented a transmission of 12,000 to 14,000 B.t.u. per sq. ft. per hour; as a matter of fact the author is of the opinion that half of this rate would be a reasonable margin of safety. The inefficient circulation which sometimes results in overheating is responsible for this low transmission.

The war period has shown the mercantile service what can be done with water-tube boilers, and the author is of the opinion that the majority of new ships which will be built in the future will be fitted with water-tube boilers of some type or other because of the efficient and satisfactory performance of the same in the past, and after all it is a type of boiler which can always be depended upon to give 40 to 50 per cent of the rated capacity without injury to the tubes or the shell.

Mechanical stoking in conjunction with mechanical draft is also having serious consideration, and a large number of Babcock & Wilcox marine boilers are being fitted with several types of forced-draft stokers. However, there are certain disadvantages which must be referred to. Particularly where ships are already in service it is somewhat difficult to install the stokers, but where new ships are being built arrangements can easily be made whereby the designs can be so altered as to include the handling of the coal and ashes on an economical basis. Other disadvantages are the extra weight and complication involved, and also the difficulty of finding mechanical stokers suitable for the various classes of fuels which have to be dealt with on board ship. This difficulty, however, is gradually being overcome and the results as far as the author has been informed are very promising indeed. It is also difficult to show that mechanical stoking is an improvement over good hand firing, but the fact remains that it is difficult to find a really good fireman who will fire a boiler as efficiently and skilfully as a mechanical stoker. With a mechanical stoker one will always obtain a steady pressure. It is not necessary to clean out fires because the stokers are self-cleaning, and, taking a general view, the author is of the opinion that sooner or later a big percentage of the ships now sailing will have mechanical stokers fitted where it is absolutely necessary that vessels have to be kept to coal fuel. There can be no doubt that the water-tube boiler with its large combustion chamber can be made to suit and is far better adapted to the mechanical stokers than the cylindrical boiler, and it is on these lines that improvements are likely to materialize.

The author strongly advocates the use of oil fuel and discusses briefly the various types of oil burners. From his own tests on ships of the H-type using the forced draft he suggests that where this is done it is desirable, in order to control fully the operation of the boiler, to have the speed of the fan engines regulated by some automatic device so that when the boiler pressure rises to the working pressure the fan engine is slowed down, and when the boiler pressure falls, say, 2 or 3 lb., below the blow-off pressure the engine is speeded up again.

During the trials at which the author of this paper was present he noticed that the regulation of the fan-engine speed had to be undertaken very frequently, taking up the attention of the leading fireman when he might have been otherwise engaged. To get over a difficulty of this description an automatic fan-engine control fitted to a steam supply pipe and thence to a fan engine was designed. Fig. 3 illustrates this as working in conjunction with the Babcock & Wilcox boiler, stoker-fired.

This consists of a double-seated balanced valve, diaphragm-operated. The diaphragm chamber is connected by a copper pipe to either the boiler or the main steam pipe so that when the steam rises to blowing-off pressure the diaphragm is depressed and automatically closes the valve, shutting off steam to the engine. The reverse process takes place when the pressure is relieved due to the steam pressure falling back, say, 2 or 3 lb. This is a very useful control and has been used in a number of ships, the result being that the fireman does not require to trouble himself about regulating the speed of the fan and can devote his time to other matters.

The author further describes and advocates the use of water-level regulators such as the Babcock & Wilcox and the Crosby.

Usually when new steamers are taken over by the superintendent, and the chief engineer is installed, he is not furnished with all the records which the author considers he is entitled to.

In running trial trips it is the custom of the engineering staff responsible to the builders to take draft readings and flue temperatures at various positions in the boiler, and it is the author's contention that a set of these figures should be furnished to the chief engineer so that he can with similar instruments take records, and by these means be able to keep the water-tube boilers working in an efficient manner. The author quotes a case in point where the rate of burning per square foot of grate area was in the vicinity of 20 lb. The temperature of the escaping gases at a point in the uptake was 510 deg. fahr. The evaporation per square foot of heating surface was 4 lb. CO_2 readings ranged from 10 to 12 per cent, making an overall efficiency of 73 per cent. The engineer complained when his ship arrived back in port that he was burning too much coal, and that, therefore, the particular water-tube boiler was not efficient. It was, however, pointed out that he had never cleaned the exterior surface of the tubes and it was probable that the gases were passing into the chimney at a very high temperature. After investigation this was proved to be correct, and that particular chief engineer demanded a flue pyrometer, draft gages, and a portable CO_2 tester, and was able on his next trip to report that the escaping gases kept in the vicinity of 510 deg. fahr.; and, generally speaking, this investigation sharpened up the wits of the engineers in that particular ship and made them very keen to obtain low running costs. (Paper read Apr. 17, 1923 before the *Institute of Marine Engineers*, abstracted from advance proof, illustrated, pc)

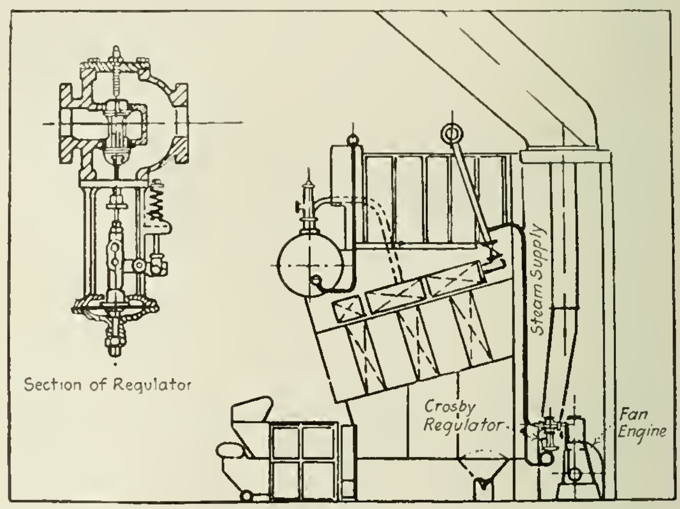

Fig. 3 Fan-Engine Control for Stoker-Fired Babcock & Wilcox Marine Water-Tube Boiler

MOTOR-CAR ENGINEERING

Andrade Differential for Motor Cars

New Differential for Motor Cars. Description of a design of differential developed by C. Andrade, Jr. It is a gearless, self-locking type and is so arranged that it delivers most, or if necessary,

all of the power transmitted to the wheel that has the most resistance on the roadbed, and therefore prevents the vehicles in which it is installed from stalling when one wheel only has traction and the other wheel is on slippery footing.

In this differential the outer or driving member is made in three parts, two of which are identical flanged hubs and the third a drum, the inner surface of which is broached to form a number of cylindrical surfaces, the axes of which lie in a cylindrical surface whose axis is the axis of rotation of the differential. The two inner driven members are splined to the axle ends and have external surfaces which are true cylinders of equal diameter. Between the driving and the driven members lie two sets of rollers, of such diameter that they clear the arcs or cylindrical surfaces of the driven member when the latter is in neutral position, as shown in Fig. 4. When the driving member starts to move ahead, the rollers all lock after they have moved about $^1/_{16}$ in. behind the center of the eccentric arcs, due to the wedging action which results.

When one of the rear wheels start to run ahead of the master gear, as the outer wheel does when the car rounds a curve, the rollers engaging that driven member roll out of locking contact and go back to the centers of the eccentric arcs. They cannot go beyond this point for the reason that the control members

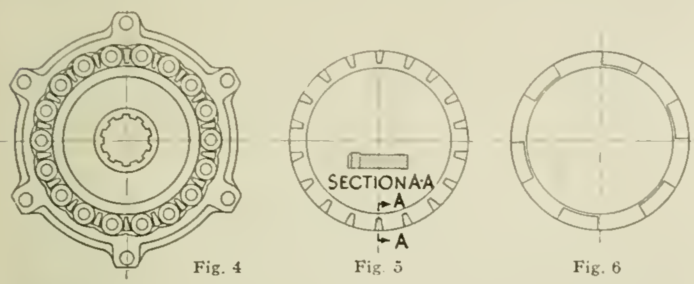

Fig. 4 Fig. 5 Fig. 6

Figs. 4, 5 and 6 Assembly and Parts for the Andrade Differential

shown in Figs. 5 and 6 prevent them from so doing. The control members are provided, on their back faces, with lugs similar to the jaws of a positive clutch, which permit them to turn only $^1/_{16}$ in. in relation to each other.

In backing the action of the differential is precisely the same as in forward motion and it also permits the normal operation of the car when the latter is going down hill and the engine is used as a brake driven from the car wheel.

Because of the large number of rollers, their considerable length, and their distance from the axle center, there is said to be only a small fraction of compressive stress on each inch of length of the rollers as there is on the gear teeth of the ordinary gear-type differential. (*Automotive Industries*, vol. 48, no. 18, May 3, 1923, pp. 979–980, 6 figs., *d*)

POWER-PLANT ENGINEERING (See Marine Engineering; Testing and Measurements)

RAILROAD ENGINEERING (See also Special Machinery)

Kunze-Knorr Air Brake. Description of a new type of air brake recently introduced on the State Railways of Sweden. It works on the principle of a single-cylinder automatic compressed-air brake.

The graduation up and down is obtained by placing a pressure transformer between the auxiliary reservoir and the valve chamber of the triple valve, by means of which the pressure in these two chambers rises and falls together in such a way that the pressure in the valve chamber of the triple valve is always higher by a certain ratio than it is in the auxiliary reservoir.

In an editorial in the same issue a careful analysis of the probable performance of the new brake is made and the conclusion to which the writer comes is that it does not appear that the new brake possesses any real advantage over the brakes that are used in the United States. (*Railway and Locomotive Engineering*, vol. 36, no. 5, May 25, 1923, pp. 143–147, illustrated, and editorial, pp. 149–150, *d*)

Newest German Type of 3-Cylinder Mikado. Description of a standard fast-freight Mikado locomotive, which is the most recent type developed in Germany. It is of the single-expansion type using superheated steam and is said to present many advantages.

It employs a crank axle, a feature which might be objected to, although with two cylinders placed outside and one inside of the frames so that the cranks form exactly or nearly an angle of 120 deg. with one another, the design of the crank axle is very simple and its manufacture is cheap compared to that of the four-cylinder locomotive which many railways were forced to abandon owing to the difficulty of manufacturing the crank axle.

The Mikado locomotive described here weighs 216,000 lb. It is intended for operation in heavy passenger as well as fast freight service and is designed for operation up to the maximum speed limit on the German railways, which is 120 km. (74.5 miles) per hour. In this locomotive the usual arrangement is found in that the main rod is connected to the second pair of driving wheels, while the return crank actuating the Walschaerts valve motion is connected to the third pair of driving wheels. This enables the use of a long eccentric rod, which serves to minimize any effect that vertical spring play of the axle in the frames may have upon the action of the valve. The piston valve controlling steam admission and exhaust from the inside cylinder is actuated by a separate valve gear connected to an eccentric crank on the left side of the locomotive. Extended piston and valve rods are used throughout.

The special equipment for this locomotive includes a pyrometer and speed indicator, also steam heat regulator. (*Railway Review*, vol. 72, no. 18, May 5, 1923, pp. 757–760, 7 figs., *d*)

SPECIAL MACHINERY

Diesel-Engine Dredge. The dredge *Elizabeth Pfeil*, the first of its type to be constructed, is equipped with Diesel-electric drive. The reason for this innovation is a practical one as the dredge is intended for service in the impure-water regions encountered in the Ohio and other rivers in the Pittsburgh district, this impure water being highly detrimental to boiler tubes.

The dredge is equipped with a 300-hp. Diesel-type, four-cylinder two-cycle, self-injection, oil-burning engine and is direct-connected to a 270-kva., 60-cycle, three-phase, 440-volt generator which drives the machinery of the entire boat.

The excavating equipment of the ladder type is made up of an endless chain of 87 manganese-steel-lipped steel buckets of 8 cu. ft. capacity weighing 1500 lb. each. This chain is mounted on a structural-steel ladder 95 ft. long, the total weight of the ladder and chain of buckets being 125 tons.

The entire operation of the dredge is controlled by one man in an elevated pilot house where there are twelve levers. From this pilot house the operator has a perfect view of the ladder and bucket line. The action of the bucket line is controlled directly by five levers connected to a 5-drum winch on the port side of the dredge forward of the tumbler center line. This winch is direct-connected by gear to a 125-hp. motor. Irrespective of the position or speed of the bucket line, complete control of the ladder and bucket line is effected at all times through brakes on the winch which hold the ladder in any position. (*Oil Engine Power*, vol. 1, no. 4, Apr., 1923, pp. 182–183, 2 figs., *d*)

Vertical Plate-Milling Machine. Description of two new tools built by Alfred Herbert, Ltd., Coventry, England, for reducing the thickness of copper plates as used in the construction of locomotive fireboxes.

Hitherto this job was done by swaging the metal down by hammering. With the new machine the preparation of the plates is reduced to a simple milling operation capable of being performed at high cutting speeds and feeds. Actual production times for this machine are not available at this moment. The machine is intended for a specific object, milling at any point on the surface of plates that may be anything up to 6 ft. sq. by $1^1/_2$ in. in thickness. It is provided with a work table of large area having longitudinal, transverse, and rotary motions and a vertical column with a long overhang to carry the spindle slide. Therefore it is possible to traverse

the plates in any direction and for the spindle to reach to the center of the maximum-size plates likely to be dealt with. The machine is not provided with low spindle speeds, but there is a range of eight of the spindle speeds varying from 100 to 350 r.p.m. which are suited for machining copper. In other respects the machine is designed and operated on the same lines as a standard vertical milling machine. The original article illustrates and describes it in considerable detail.

In conclusion it may be mentioned that the leading dimensions of the machine allow for a longitudinal feed of 78 in. and a transverse feed of 39 in. The maximum distance from the surface of the table to the end of the spindle is 13 in., while the distance from the center of the spindle to the vertical face of the column is 42 in. The working surface of the table is 78 sq. in., and the total floor space occupied by the machine is 17 ft. 6 in. sq., and its approximate net weight 40,000 lb. (*Machinery*, London, vol. 22, no. 552, Apr. 26, 1923, pp. 117–120, 4 figs., *d*)

SPECIAL PROCESSES (See Engineering Materials)

STEAM ENGINEERING (See Thermodynamics)

TESTING AND MEASUREMENTS

A Method of Determining Loss of Heat in Flue Gases Due to Incomplete Combustion, O. I. Hanson and K. E. Nielsen. An investigation conducted by the Danish Society of Fuel Economy into the composition of waste gases from steam generating plants and central heating furnaces has shown that their content of unburned gases is higher than is generally appreciated. The method of analysis by which unburned gases can be determined within a small limit of error and the calculation of heat loss from the results obtained are described in the paper. The apparatus works with a view to obtaining all the data by a single combustion analysis after the removal of carbon dioxide, and is therefore essentially different from the Orsat apparatus; it is described in detail in the original article and the errors of calculation are carefully considered. From this it would appear that the maximum percentage error of calculation of the calorific value of the fuel will only occur when either methane alone or hydrogen alone are present mixed with the carbon monoxide, and even then apparently the error will not be large enough to affect practical results. (*Fuel in Science and Practice*, vol. 2, no. 4, May, 1923, pp. 115–120, 4 figs., *d*)

THERMODYNAMICS

An Imaginary Thermodynamic Process, Jos. S. Ames. An article is not suitable for abstracting. The author assumes the existence of a being who has no knowledge of space or of space measurements but has sense organs for temperature, entropy, and force, and instruments for giving numbers to them. He makes certain other assumptions and then shows how such a being would have no trouble in comprehending the true nature of entropy. This is supposed to facilitate the understanding of entropy by ordinary students of thermodynamics. (*Journal of the Franklin Institute*, vol. 195, no. 5, May, 1923, pp. 655–663, 1 fig., *tA*)

The Supersaturation Limit—Steam at Wilson Line

The Supersaturation Limit, H. M. Martin. The author has compiled new tables of the properties of steam at the Wilson line to replace those given in his New Theory of the Steam Engine. In compiling these tables a new formula has been derived for the ratio between the actual pressure of the supersaturated steam and the pressure corresponding to the temperature. This formula is

$$\log_{10}\frac{p}{p_s} = \frac{2.96\sigma}{T}$$

where p is the actual pressure of steam when condensation commences, p_s the pressure corresponding to the absolute temperature T, and σ is the surface tension of water at that temperature. The complete derivation of this formula will be found in the original article.

The last column of Table 1 shows what the volume of the steam would have been, had it expanded in thermal equilibrium, while the column headed t_s shows the corresponding temperature. It will be seen that at the Wilson point the defect of temperature is about 28.7 deg. cent. when the condensation occurs at —10 deg. cent. The specific volume of steam at the Wilson line is very approximately 90 per cent of the specific volume at the same pressure, but at the saturation line.

The experiments of Professor Stodola confirm the view that at all temperatures the limit of supersaturation is fixed by the presence of co-aggregated molecules, the dimensions of which are independent of the temperature.

The data now most urgently required are the relationships between the pressure and volume of the steam when the expansion extends beyond the Wilson line. Mr. Wilson found in his own experiments that in this case the further condensation came down on new nuclei instead of on the droplets already formed. This shows that the temperature of the steam in this further expansion must have been that corresponding to the Wilson line and not to the saturation line. This conclusion is confirmed by the measurement of the temperature of the exhaust from steam turbines, which is commonly found to be perceptibly below the saturation temperature corresponding to the pressure. Since any thermometer placed in supersaturated steam records, not the temperature of this steam, but merely the temperature of the film of moisture which condenses on its surface, the slight defect of temperature observed is no doubt an indication of a very much larger true defect. As matters stand, however, we have no information as to the relationship between pressure and volume during most of the expansion through a low-pressure turbine, but are obliged to rely on purely empirical rules.

TABLE 1 PROPERTIES OF STEAM AT THE SUPERSATURATION LIMIT OR WILSON LINE

Temperature at Wilson point, deg. cent.	Pressure at Wilson point, lb. per sq. in.	Ratio $\frac{p}{p_s}$	Volume at Wilson point, cu. ft. per lb.	Total heat at Wilson point, lb. cent. units	Entropy at Wilson point	Equilibrium temperature, deg. cent.	Equilibrium volume, cu. ft. per lb.
t_w	p_w		V_w	H_w	ϕ_w	t_s	yV_s
—10	0.3140	7.485	896.59	589.36	2.11023	18.69	973.27
0	0.6000	6.724	486.18	594.00	1.96601	29.53	526.26
10	1.086	6.074	277.99	598.58	1.91765	40.29	300.43
20	1.875	5.517	166.37	603.07	1.87388	50.96	179.48
30	3.103	5.035	103.76	607.48	1.83419	61.56	111.78
40	4.940	4.615	67.114	611.76	1.79811	72.09	72.182
50	7.602	4.249	44.831	615.89	1.76522	82.55	48.155
60	11.34	3.926	30.496	618.06	1.73527	92.90	32.700
70	16.43	3.639	21.801	623.67	1.70789	103.17	23.364
80	23.23	3.385	15.774	627.30	1.68282	113.35	16.988
90	32.12	3.162	11.642	630.72	1.65965	123.46	12.455
100	43.46	2.959	8.775	633.97	1.63850	133.47	9.378

The determination of the true relationship between the pressure and the volume of the steam during an expansion beyond the Wilson line, should not present any insuperable difficulties. All that would seem necessary is the taking of an accurate indicator diagram by optical means under conditions in which the volume occupied by the steam was accurately known at each point of the stroke. No expensive special apparatus would seem to be necessary. The cylinder need not be more than, say, 1 in. in diameter, and its base might well form the elastic diaphragm of the indicator, while the movement of the piston might be effected by a falling weight. In order to insure a complete absence of moisture it would no doubt be advisable to work with steam which was slightly superheated at the outset. By jacketing the cylinder and piston with steam at the initial temperature no moisture would be deposited on these, while the amount of heat which could pass from these surfaces into the expanding steam during the small fraction of a second occupied by the stroke would be negligible. (*Engineering*, vol. 115, no. 2994, May 18, 1923, p. 607, *tA*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

ENGINEERING RESEARCH

A Department Conducted by the Research Committee of the A.S.M.E.

Résumé of the Month

A—Research Results

The purpose of this section of Engineering Research is to give the origin of research information which has been completed, to give a résumé of research results with formulas or curves where such may be readily given, and to report results of non-extensive researches which in the opinion of the investigators do not warrant a paper.

Framed Structures A2–23. Compression Tests of Structural Steel Angles. This article, known as Technologic Paper No. 218, presents the results of compression tests of 170 structural angles, made at the Pittsburgh branch, Bureau of Standards, by A. H. Stand and L. R. Strickenberg. The object of the tests was to determine the ultimate compressive strength of angles fastened at the ends in such ways as would closely correspond to their connections in the construction of transmission towers. There was also tested a series of angles with square ends. An end fixation factor was found to represent satisfactorily the effect of different types of end connections. Using this fixation factor, the average values for large slenderness ratios were well represented by Euler's formula. The results obtained from shorter columns agreed with the experimental and theoretical results of Karman. The effect of eccentric loading was most marked at the slenderness ratios indicated by Karman's theory. Price per copy, 10 cents. Address Superintendent of Documents, Government Printing Office, Washington, D. C.

Properties of Engineering Materials A2–23. Some Tests of Steel-Wire Rope on Sheaves. This Technologic Paper No. 229 has been just published by the Bureau of Standards. It was prepared by Edward Skillman from data obtained as a result of tests made at the request of the erection department of the American Bridge Company.

Tests of wire rope $^5/_8$, $^3/_4$, $^7/_8$, 1, and $1^1/_4$ in. in diameter were made on sheaves of 10, 14, and 18 in. diameter to determine their strength under static load. The ropes were all of 6-strand, 19-wire construction made from "plow" steel. It was found that the strength on sheaves was less than that of the straight ropes, the ratio of the strengths being 0.87 for $^5/_8$-in. rope on 10-in. sheaves and 0.95 on 18-in. sheaves; for $1^1/_4$-in. rope the corresponding values were 0.76 and 0.85.

The tensile strength of individual wires was about 230,000 lb. per sq. in., elongation in 8 in. about 2 per cent, and reduction of area about 46 per cent. These were practically the same for all sizes of wire. The strength of the straight ropes followed closely the equation S = 83,000 d^2, in which S is the strength in pounds and d the diameter of the rope in inches. One worn rope which was tested showed a surprisingly high strength when its condition is considered.

A point of inflection in the load diagrams was found at from 56 to 65 per cent of the ultimate load, above which the elongation increased rapidly. The elongation of straight rope over a gage length of about 40 in. was about 2.5 per cent and the reduction of diameter about 4 per cent. The modulus of elasticity of a new rope was about 8,500,000 lb. per sq. in. and of worn rope about 13,500,000 lb. per sq. in.

Price per copy, 10 cents. Address the Superintendent of Documents, Government Printing Office, Washington, D. C.

Iron and Steel A5–23. Some Tests of Steel-Wire Rope on Sheaves. See *Properties of Engineering Materials A2–23.*

Properties of Engineering Materials A3–23. Investigation of the Fatigue of Metals Results of 1922. In the February, 1922, issue of Mechanical Engineering the first report of this investigation (Bulletin No. 124) was listed under "Mechanics A1–22." This second printed report was prepared by Messrs. H. F. Moore and T. M. Jasper and is known as Bulletin No. 136 of University of Illinois Engineering Experiment Station.

The tests recorded in this bulletin have all been made on specimens of wrought ferrous metal, free from flaws and large inclusions, as shown by micrographs, and tested under continuous series of cycles of stress. All specimens were turned with the longitudinal axis in the direction of rolling of the steel. The information gained from these specimens may not be true for steel with serious flaws or large inclusions, nor should such conclusions be extended to cast steel, cast iron, or non-ferrous metals. Subject to the above limitations, the conclusions drawn from the tests herein recorded may be summarized as follows:

1 A study of the test data obtained as well as of those secured from other laboratories tends to confirm the existence of an endurance limit for wrought ferrous metals, the endurance limit being defined as the unit stress below which a metal is capable of withstanding an indefinitely large number of reversals of stress.

2 The test results obtained and those from other laboratories confirm the conclusion drawn in Bulletin No. 124 that the endurance limit of a wrought ferrous metal may be determined with a fair degree of accuracy by a short-time test in which the rise of temperature under reversed stress is measured.

3 The tests recorded in this bulletin confirm the conclusion drawn in Bulletin No. 124 that for wrought ferrous metals the endurance limit seems to be correlated with the ultimate tensile strength, with the Brinell hardness number, and in a much smaller degree with the yield point and the proportional elastic limit. No correlation was found between the endurance limit and the ductility, the results of Charpy impact tests of notched bars, or repeated-impact tests.

4 The effect of speed of reversal of stress on the determination of the endurance limit seems to be slightly below a speed of 5000 r.p.m. for tests made on a Farmer rotating-beam testing machine. A slight increase of endurance limit was noted for increased speed of reversal of stress.

5 The results of the tests of specimens with various temperatures of "draw" after oil quenching indicate that for the carbon-steel specimens tested neither the ultimate tensile strength, the endurance limit for flexure, nor the ductility was appreciably affected by draws at a temperature lower than 600 deg. fahr. For the nickel-steel specimens for draws up to 400 deg. fahr. the ultimate tensile strength and the endurance limit for flexure diminished slightly while the ductility increased a little. For draws at higher temperatures the changes in values of strength and ductility were more marked, the ultimate tensile strength and endurance limit decreasing, and the ductility increasing. Whatever advantages may be gained by draws below about 600 deg. fahr. such as relief from internal stress and increased machinability, may be attained with but little, if any, sacrifice of tensile strength or of endurance strength under flexure.

6 The results of tests of the specimens subjected to severe tensile overstress before being tested in reversed bending indicate that a few applications of stress, well above the proportional elastic limit of the metal, lowered the endurance limit under subsequent reversed stress, the endurance being diminished by 22.9 per cent of its original value for one set of specimens. The effect of polishing the specimens after overstressing has not yet been investigated. Placing the specimens in boiling water did not seem to have any appreciable beneficial effect on the endurance limit.

7 From the test data recorded in this bulletin the following tentative formula is given for wrought ferrous metals as expressing with a fair degree of accuracy the relation between the endurance limit for cycles of completely reversed stress and the endurance limit for cycles of stress not involving complete reversal:

$$S_r = S_{-1} \left(\frac{r+3}{2}\right)$$

in which r is the algebraic ratio of minimum stress to maximum stress during a cycle of stress (for completely reversed stress, $r = -1.0$), S_r is the endurance limit for ratio r, and S_{-1} the endurance limit for completely reversed stress.

8 If a specimen or machine part is subjected to cycles of repeated-bending stress higher than the proportional elastic limit of the metal, the tests indicate that there may result a failure by excessive distortion of the specimen or the machine part. The endurance limit under repeated-bending stress should, then, never be considered as higher than the proportional elastic limit of the metal.

Iron and Steel A6–23. Investigation of the Fatigue of Metals Results of 1922. See *Properties of Engineering Materials A3–23.*

Mechanics A1–23. Investigation of the Fatigue of Metals Results of 1922. See *Properties of Engineering Materials A3–23.*

Fuel Utilization A5–23. Preparation, Transportation, and Combustion of Powdered Coal. This pamphlet, known as Bureau of Mines Bulletin 217, by John Blizard, sets forth the many methods, advantages and disadvantages of preparing and burning powdered coal, and states that manufacturers and operators of coal-fired furnaces cannot afford to disregard the advantages of pulverizing their coal before burning it.

The chapter headings, which are as follows, give a good idea of the scope of this publication: I, Powdered Coal, Definitions and General Discussion; II, Preparation of Powdered Coal; III, Distribution of the Powdered Coal; IV, Feeders, Mixers, and Burners—Bin-at-Furnace System; V, Uses of Powdered Coal; VI, Powdered Coal for Steam Raising; VII, Costs of Preparing and Delivering Powdered Coal to the Furnace; VIII, Danger from Use of Powdered Coal; and IX, Conclusions. Price per copy, 50 cents. Address the Superintendent of Documents, Government Printing Office, Washington, D. C.

Refrigeration A2–23. Tables of Thermodynamic Properties of Ammonia. These tables are the result of measurements made by the Bureau of Standards to determine fundamental physical data of refrigerating engineering. The Bureau's researches in this field were undertaken in response to the wishes of the refrigerating industry as expressed through its national associations and were specifically authorized by act of Congress. In carrying out the experimental program the bureau has had the benefit of the advice of The American Society

of Refrigerating Engineers, one of the organizations which originally requested that the work be done.

The tables, which are published in foot-pound-fahrenheit units only, embody the results of an elaborate series of measurements of the thermodynamic properties of ammonia. The fundamental units and constants used in the tables are defined. The empirical equations used in computing the tables, and also the references to the publications dealing with the experimental data, are given. The tables have been prepared in the forms convenient for use in refrigerating engineering. The same data are also presented graphically in the form of a Mollier chart.

Price per copy, 15 cents. Address Superintendent of Documents, Government Printing Office, Washington, D. C., asking for Bureau of Standards Circular No. 142.

F—Bibliographies

The purpose of this section of Engineering Research is to inform the profession of bibliographies which have been prepared. In general this work is done at the expense of the Society. Extensive bibliographies require the approval of the Research Committee. All bibliographies are loaned for a period of one month only. Additional copies are available, however, for periods of two weeks to members of the A.S.M.E. These bibliographies are on file at the headquarters of the Society.

Petroleum and Allied Substances F2-23. This Bulletin No. 216, covering the years 1919 and 1920, is the fifth in the series of petroleum bibliographies published by the Bureau of Mines, Bulletins 149, 165, 180, and 189 being compilations for the years 1915, 1916, 1917, and 1918, respectively. The publications examined number 169 and include both domestic and foreign. The references are arranged under the following headings: (000) General treatises; (100) Countries and regions; (200) Geology and origin; (300) Development and production; (400) Transportation, storage, and distribution; (500) Properties and their determination; (600) Refining and refineries; (700) Utilization; (800) Legislation and legal regulations; and (900) Miscellaneous.

Price per copy, 40 cents. Address the Superintendent of Documents, Government Printing Office, Washington, D. C.

CORRESPONDENCE

Contributions to the Correspondence Department of Mechanical Engineering are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities and policies of the Society in Research and Standardization.

The Efficiency of the Scotch Marine Boiler

To the Editor:

Mr. C. J. Jefferson's article in the April Mechanical Engineering on the Efficiency of the Scotch Marine Boiler shows very good results for the recent tests on two Scotch marine boilers by the U. S. Shipping Board and the Bureau of Mines, but there are several points regarding the tests which differ from marine practice and which should be added to his article.

One of the most noticeable things in the test is the variation in the average feedwater temperatures, which ranged from 288 to 212 deg. fahr., with one temperature of 232 deg. It is interesting to note that the highest boiler efficiency was obtained with the lowest average feedwater temperature used in any of the runs. Had a higher feedwater temperature been used in this run the boiler efficiency would have undoubtedly been higher, as by a rule of thumb a saving of one per cent in fuel is obtained for each increase of 10 deg. fahr. in the temperature of the feedwater. This is one of the things about which marine engineers are particularly careful, and temperatures of from 220 to 230 deg. fahr. are the usual practice, and are obtained by having a back pressure of between 2 to 6 lb. gage on the auxiliary exhaust which is used to heat up the feedwater. Higher temperatures up to 240 deg. are sometimes used, but any temperature requiring an auxiliary exhaust pressure more than 10 lb. gage is not good practice. By carrying a high feedwater temperature there is a saving in fuel, and this temperature is easily read with a thermometer. The adjustment of the valves to carry the proper auxiliary feed pressure for the desired feedwater temperature is readily made and need not be changed ordinarily under constant working conditions.

The introduction of flue-gas analysis has been slow in marine work, probably due to the idea that it is a complicated process. It also requires chemicals of known strength, which are not readily obtainable everywhere, and some of them are liable to deteriorate if not kept properly. It is true that flue-gas analysis requires a certain knack to obtain proper results, but given a few simple instructions, it would seem that marine engineers would quickly learn to make accurate readings. After using this method to learn what is going on in the furnace, and making the required changes in the operation of the boilers to suit such an analysis, a very real saving in fuel would result in a large number of cases. The use of automatic CO_2 and CO recording instruments has not been possible, due probably to the delicacy of the instruments, which are so devised that they can only be used for stationary work.

Pyrometers are used in navy work to indicate the temperature of the gases as they leave the boiler. It seems that they would be equally valuable in merchant-marine work, and would afford the engineer some indication of how much heat is going up the stack and being wasted.

The marine engineer is also handicapped by not having a definite means provided for measuring the amount of water fed to the boiler, and when using coal for measuring the exact amount fired. Approximations may be used in both cases—for example, so many pounds of coal in a wheelbarrow—and with a well-made-up system of piping and no free escapes of steam the amount of make-up feed used is a fairly definite proportion of the water fed to the boilers. Also for a complete analysis of boiler conditions an instrument for determining the quality of the steam—if not superheated—would be required.

A further important thing in marine work is the use of a calorimeter for determining the fuel value of the coal or oil used. This would give the engineer an idea of the quality of the fuel he was using, and would also be of great value in its purchase. The recent high price of coal and its poor quality will undoubtedly hasten the use of a calorimeter for this work.

Such items as keeping the boiler clean by opening at the proper intervals, blowing the tubes regularly, keeping the boiler water slightly alkaline and not too salty, and all apparatus in good working condition, are too well known to need any discussion.

These, then, are the principal items in which it seems to the writer that this test differs from ordinary present merchant-marine practice. In addition he does not himself know of any case in marine work where the gases leaving the furnace are used to heat up the air fed to the boiler, but of course this system is valuable as far as the boiler efficiency is concerned.

Washington, D. C. Charles D. Shepard.

[Mr. Shepard's communication was placed before Mr. Jefferson, the author of the paper, from whom the following letter has been received.—Editor.]

To the Editor:

In regard to Mr. Shepard's letter commenting on the article on Scotch marine boilers, the writer would like to submit the following remarks:

1 *Feedwater Temperature.* All the efficiencies as listed in the heat balance of this test were determined from the equivalent of the evaporation figures which automatically take care of the feedwater temperature.

The writer has found it common practice in marine service to operate with 15 lb. back pressure, and on several of our best performers we have gone still further and installed a second feed heater which utilizes the auxiliary exhaust from such auxiliaries as are run on full boiler pressure, these auxiliaries being run at 35 lb. back pressure. The purpose of the second feed heater using the higher

back pressure is to boost up the feed temperature to about 270 deg. This has resulted in increased economies as high as 7 per cent of steam for our turbine-driven ships where the auxiliary steam being taken away from the main condenser permitted higher vacuums to be obtained on the main unit and the increased boiler-feed temperature resulted in reduced maintenance charges.

2 *Flue-Gas Analysis.* Mr. Shepard comments regarding the fact that the adoption of flue-gas analysis for the use of determining boiler efficiencies in marine practice has been somewhat slow. You are advised that we have found this only too true, and it is to overcome such conditions as this that the Fuel Oil School has been started at the Philadelphia Navy Yard. It is proper to say, however, that while there were practically no Orsats in use in our fleet a year ago, now practically 50 per cent of the vessels are equipped with this instrument and the *engineers are using them.*

3 *Use of Pyrometers.* The pyrometer has been installed for some time in merchant vessels, but in common with a great many other similar power-plant installations, proper regard has not been given to its location. In order to get really worth-while data for operating purposes, it is necessary that the pyrometer be installed as close as possible to the point where the gases leave the boiler. This in the Scotch boiler really means, on a three-furnace job, three pyrometers. When the pyrometer is installed in the stack halfway up the fiddley, the temperatures observed are not trustworthy for determining efficiency of operation as this temperature is generally affected considerably by minor leakage through breachings and uptakes.

4 *Use of the Fuel Calorimeter.* The writer's personal experience with the fuel calorimeter forces him to the conclusion that this is a laboratory instrument, and if used by inexperienced persons would lead to very erroneous conclusions.

5 *Use of Air Heaters.* Mr. Shepard states that he knows of no case where the gases leaving the furnaces are used to heat up the air fed to the boiler. This system of air heater was developed by James Howden a number of years ago and is in use on practically all Scotch boiler installations, as well as the majority of the large passenger vessels such as the *Leviathan,* etc.

New York, N. Y. C. J. Jefferson.

Locating Leaks in Underground Pipe Lines

To the Editor:

Locating leaks in underground steam and water lines is usually expensive. In the case of steam and return lines the first evidence appears as steam from the manholes or water or steam from the outlets of the underdrains. The exact location of the leak is determined by putting down one or more test excavations along the line until the leak is found.

The geophone, an instrument developed during the war for detecting vibrations of the earth due to tunneling, etc., was recently tried for locating leaks in underground piping systems of an eastern university with the following results:

The first leak was in the return of the heating system and was located accurately under 4 ft. of cover.

The second leak was in a domestic hot-water pipe encased in a concrete duct packed with mineral wool and under 4 ft. of cover. The line extended from a tunnel to a building 250 ft. away. The evidence of the leak appeared as warm water from the underdrain into the tunnel. The leak was located 200 ft. from the tunnel and proved to be a pit hole in the pipe about $^3/_{16}$ in. in diameter.

The third case was in a 5-in. steam line carrying 10 lb. steam pressure. The line is encased in a concrete duct. The leak was located at a point which proved to be $9^1/_2$ ft. underground.

In all these cases the leaks were plainly audible for ten or more feet each side of the point at which it was finally decided that the disturbance was loudest. In each case the first excavation put down centered on the leak.

The above trials indicate that the geophone can be very profitably used for locating leaks in like underground lines. [Its use in locating leaks in compressed-air lines was described in Mechanical Engineering, November, 1922, p. 741.—Editor.] The instrument and some of its applications are described in Technical Paper 277, Department of the Interior, Bureau of Mines.

Ithaca, N. Y. H. A. Ward.

A.S.M.E. Boiler Code Committee Work

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society, for approval, after which it is issued to the inquirer and simultaneously published in Mechanical Engineering.

Below are given the interpretations of the Committee in Cases No. 412–417, inclusive, as formulated at the meeting of March 22, 1923, and approved by the Council. In accordance with the Committee's practice, the names of inquirers have been omitted.

Case No. 412

Inquiry: Is it permissible, under the Code, to use on boilers, pressed-steel nozzles having the upper or bolting flange of the Vanstone joint construction, with the bolt-flange made of steel?

Reply: While the form of construction proposed for a boiler nozzle embodying the use of the Vanstone joint, as outlined, does not conflict with the requirements of the Code, provided the flange, dimensions, etc., meet the requirements of the Code for pipe flanges, it is the opinion of the Boiler Code Committee that a rigidly attached form of nozzle flange is preferable.

Case No. 413

Inquiry: What is the permissible stress for screwed stays with ends riveted over less than 20 diameters in length, when such screwed stays are inserted in the sheets at an angle that is not truly radial in the case of curved plates, or in the case of flat plates is not normal to the plane of the plate?

Reply: It is impossible to formulate any logical requirement for a condition of that sort and it must be a matter of judgment. A revision of the Code has been proposed which reads as follows:

"All staybolts not normal to the stayed surface shall have not less than three engaging threads, of which at least one shall be a full thread."

The angularity in such case should not exceed 15 deg. to the stayed sheet. If the angularity is greater than 15 deg. it must be taken into account in calculating the permissible stress in the staybolt.

Case No. 414—(In the hands of the Committee)

Case No. 415

Inquiry: Where a boiler of the locomotive type is fitted with a form of removable drum, attached by bolted connection to the outlet nozzle, as is customary practice in the California oil fields, is it the intent of the Code that the requirements of Par. 194 shall apply to the construction of the drum, or can this construction be considered as a steam drum subject to the requirements of Par. 187?

Reply: It is the opinion of the Boiler Code Committee that the form of construction shown is not a boiler dome and therefore does not come under the requirements of Par. 194 of the Code, but must be considered as a steam boiler drum coming under the provisions of Pars. 187 and 188.

Case No. 416—(In the hands of the Committee)

Case No. 417

Inquiry: Is it the intent of the Code to require any particular design for suspension lugs to support horizontal-return-tubular boilers 78 in. or less in diameter?

Reply: It is the opinion of the Committee that it was not the intent of the Code to require any particular design for suspension lugs to support horizontal return-tubular boilers 78 in. or less in diameter, but that any such lugs should conform to the requirements of Pars. 324 and 325 of the Code.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

The American Society of Mechanical Engineers

29 West 39th Street, New York

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Uniform Safety Legislation

Harris and Ewing
M. G. Lloyd

THE administration of industrial accident prevention in this country differs widely from state to state. Legislation is now in force in different states providing either: (1) a commissioner of labor statistics whose duty is to collect and report information; (2) statutory requirements for accident prevention; (3) statutory requirements for accident prevention supplemented by a staff of factory inspectors to enforce these requirements; (4) a board or commission having power to make detailed regulations—usually with reference to only one subject or industry; (5) officials or commissions with power to make detailed regulations for industries in general, with a staff of inspectors to enforce both statutory requirements and commission orders.

The experience which has now been obtained is sufficient to enable us to form a definite idea as to the type of legislation which will secure the best results, although this idea may have to be modified to some extent by local differences in political or industrial conditions. It should be noted that most of the prominent industrial states have adopted the method of delegating the legislative authority for enacting regulations to the administrative officials who are concerned with the enforcement of the regulations, and whose regular duties bring them into contact with working conditions as they are met in industry. There are now 17 states where such powers for industries in general have been given to an industrial commission or similar officials, and there are others where similar powers with respect to mining or public utilities reside in a separate commission. This may be regarded as the complete development of the system of protection for the worker against industrial accidents. This system has the advantage over statutory requirements that the regulations may be changed with comparative ease when experience, advancement in the arts, or wider knowledge of industries and processes shows such amendment to be desirable. It is then unnecessary to wait for a legislative session or to convince legislators, who are unfamiliar with the details of the matter and who are largely occupied with matters of a political nature, of the desirability of the change. It is also possible to cover additional industries or new conditions in old industries as soon as the subject may demand attention. It is also possible to give the detailed requirements much more extensive and more technical study than it is possible for legislators to give. The regulations are consequently likely not only to be more complete and more adaptable to conditions, but also more satisfactory both to the inspector and to those who must comply with them.

It would consequently seem desirable in future legislation on this subject that those who are attempting to improve present conditions should work toward the establishment of administrative authorities with full powers to make the detailed regulations which are to be enforced, and to combine with this the authority to amend regulations which have already been placed upon the statute books. In many cases such regulations have become obsolete before they have been repealed or amended by later statutes. This is one of the most objectionable features of detailed statutory requirements, which usually do not permit exercise of any discretion upon the part of the inspector or administrator.

M. G. Lloyd.[1]

The Pittsburgh Power Survey

TWO YEARS AGO public attention was attracted and the popular imagination fired by an announcement by the United States Geological Survey that a superpower system was being planned for the region between Boston and Washington. In its report on the subject the Geological Survey pointed out the possibilities of great economies in power production by interconnection and combination of power-producing facilities. The investigation on which the report was based was prompted by a far-seeing idea that economical power production must be the basis for future industrial expansion, and a requisite for the advance of our civilization.

In the discussion of papers on hydroelectric development at the Spring Meeting of the Society, William M. White called attention to the facts that the productivity of the workers of each country and the rates of wages paid to each worker bear a definite relation to the amount of mechanical power per worker. He also emphatically stated that the public must look to the engineer to point the way in developing nature's resources to minimize human toil. The utilization of power to meet the needs of our industries and to provide the many varied articles that make modern life possible is therefore a grave responsibility of the present generation of engineers. To bear this responsibility properly, however, the engineering profession must have facts, and many careful studies, such as those relating to the superpower system, must be carried on.

The investigation recently conducted in the steel industries in the Pittsburgh district, as reported in the leading article by Professors Ely and Rittman in this issue of Mechanical Engineering, furnishes important facts upon which principles for the more economical use of power and fuel may be based. An interpretation of the facts and trends of this paper lead to a much more thorough appreciation of the importance of power in all the American industries.

The effect of this survey in the Pittsburgh district itself must have been very helpful. It emphasized as the authors point out, the need for greater completeness and uniformity of power and fuel records in the steel industry. It has brought out coöperation between the various components of the steel industry and the producers of electrical energy in the district.

The results of the study bear witness to the confidence the industries of Pittsburgh place in the Carnegie Institute of Technology and in the authors. Such confidence must be the basis on which accurate statistics of this kind are developed.

The Engineer's Job

THE quotation on the cover of this issue of Mechanical Engineering is from an address delivered before the Engineers' Club of Philadelphia as reported in the January issue of *Engineers and Engineering*. Dr. Frank Aydelotte, the author of the quotation, in addition to being President of Swarthmore College, is American Secretary of the Rhodes Trustees, a trustee of the Carnegie Foundation for the Advancement of Teaching and a member of a number of educational and scientific bodies.

[1] Chief of Safety Section, Bureau of Standards, Washington, D. C.

World Power Conference

A WORLD Power Conference will be held in London next year to determine how the industrial and scientific sources of power may be adjusted nationally and internationally. This conference is to be held at the time of the British Empire Exhibition, but is an independent undertaking under the auspices of the British Electrical and Manufacturers' Association. General committees are being formed in Great Britain, France, Italy, Norway, Sweden, Czechoslovakia, Canada, and other countries, to arrange for participation in the conference. Members of engineering organizations in the respective countries are serving on these committees.

In the United States, a preliminary meeting was held on February 8 to consider participation by this country. A special committee, consisting of J. W. Lieb, Chairman, H. J. Pierce, Calvert Townley, W. H. Onken, Jr., F. R. Low, and O. C. Merrill, was appointed to draw up a plan of organization. Its report was submitted and approved at a second meeting on May 4. A final organization meeting was held in New York on June 20, at which engineering and technical societies, business associations interested in power, and government agencies were represented, making up the general committee. The organization for this country's participation was effected and an executive committee chosen to work out the details. Members of the national societies who are serving on the general committee are Peter Junkersfeld and George C. Orrok, A.S.C.E.; D. B. Rushmore, A.I.M.E.; and F. R. Low, D. B. Rushmore, and F. D. Herbert, A.S.M.E.

This important conference is one of a series of international events in which the American engineers are participating, all tending to strengthen the international bonds between engineers.

French Engineering Society Celebrates Seventy-Fifth Anniversary

IMPRESSIVE excerises marked the three-day celebration in Paris, May 4, 5, and 6, of the seventy-fifth anniversary of the founding of the Société des Ingénieurs Civils de France. The American Society of Mechanical Engineers was represented at the celebration by Past-President Jesse M. Smith and Laurence V. Benet, Honorary Vice-Presidents for the occasion by Council appointment.

Mr. Smith was selected by the Société to be spokesman for all the American societies represented at the opening reception and he delivered an appropriate and eloquent address.

The principal session on May 4 was presided over by M. Millerand, President of the French Republic. Two technical papers were presented: The Metallurgical Industry, by M. R. Jordan, and Large Electric Transmission Systems, by MM. Janet and Bizet.

The feature addresses, however, were delivered the following morning, when General Ferrie spoke on Hertzian Waves and Their Application, M. Soreau on Aeronautics, and M. Percheron on the Guidance of Airplanes by Radiotelegraphy. This session was followed by an excursion to Bourget, where the installation and organization of the greatest airport in the world were examined in detail. The regularity of the arrival and departure of mail- and passenger-carrying planes was most impressive, and the statistics given of the amount of mail and freight and the number of passengers carried during the past year without accident demonstrated that the air service has become an essential part of the transportation system of France.

Sunday morning, May 6, was marked by a reception to M. Eiffel given on the second platform of the Eiffel Tower. In spite of his 91 years, M. Eiffel delivered an address of welcome which was greatly appreciated by a large audience.

Several brilliant social affairs were held, the last of which was a banquet of about 400 covers addressed by delegates from all the foreign countries and by M. Le Troquer, a member of the French Cabinet. Here again Mr. Smith represented the United States of America, and his speech was warmly applauded. Sir Archibald Denny was Great Britain's representative.

Laurence V. Benet, one of the Society's representatives at the celebration, represented it twenty-five years ago at the fiftieth anniversary exercises of the French Société, and spoke then on behalf of American engineers.

Dr. de Margerie Honored by U. S. Engineers

A RECEPTION and luncheon in honor of Dr. Emmanuel de Margerie, second exchange professor from France to this country, was held at the Harvard Club, New York City, May 18, 1923. Arrangements were made by a committee of the A.S.C.E., A.I.M.E., A.S.M.E., and A.I.E.E., and the guests included present and past officers of those societies and their joint organizations; representatives of the seven universities on the exchange list; Dr. A. E. Kennelly, last year's exchange professor to France; Dr. Charles F. Scott, president of the Society for the Promotion of Engineering Education; Dr. Stephen Duggan, director of the Institute of International Education; M. Gaston Liebert, former consul-general in New York, now director of the French Bureau of Information in New York City; and M. Charles Baret, successor of M. Liebert as consul-general in New York, representating Ambassador Jusserand. Dr. A. R. Ledoux, chairman of the committee on arrangements, acted as toastmaster.

Dr. de Margerie, who during the past year has lectured at Columbia, Cornell, Harvard, Johns Hopkins, Massachusetts Institute of Technology, University of Pennsylvania, and Yale, is director of the Geological Survey of Alsace-Lorraine, and chief geologist of the Geological Survey of France. He is a member of and holds medals from leading American and French geological societies, the latest honor conferred upon him being the Mary Clark Thompson gold medal of the National Academy of Science of the United States.

Dr. Kennelly, who is now professor of electrical engineering at Harvard and M.I.T., introduced Dr. de Margerie, referring to his work, which carries him over the political boarders of France into other countries, as another illustration of what modern science is doing for us in linking us all together.

"Unity of thought" between the scientist and the engineer, the influence of the engineer in the development of the community, and the large number of educational institutions, are among Dr. de Margerie's impressions of America, as stated by him in a brief address at the luncheon. Both M. Baret and M. Liebert also spoke.

This occasion marked the close of the second year of exchange professorships in engineering and science between the United States and France. The plan, which was inaugurated by the late Dr. Maclaurin of M.I.T., purposes to bring about a closer relation of science and engineering between the two countries, through the influence of personalities as well as the exchange of ideas.

Rudolph Hering, Dean of Sanitary Engineers, Dies

RUDOLPH HERING, consulting hydraulic and sanitary engineer of New York City and an authority on municipal water supply, sewage, and garbage disposal, died on May 30, 1923. Mr. Hering was born in Philadelphia, Feb. 26, 1847. He was educated in Dresden, Germany, and was graduated from the Royal Polytechnic College of Dresden as a civil engineer in 1867. He returned to this country shortly afterward and became assistant engineer to the Board of Public Works of Philadelphia. In 1881 he visited Europe again to study sewage-disposal methods for the National Board of Health.

From 1883 to 1885 he was engineer in charge of the new water supply of Philadelphia, and during the next two years was chief engineer of the Chicago Drainage and Water Supply Commission. From 1888 until 1920, when he retired from active practice, Dr. Hering was engaged in consulting work for water supply and sewage works for practically all of the larger cities in the United States and Canada. As a member of a New York firm of consulting hydraulic and sanitary engineers for many years he served the Department of Water Supply, Gas and Electricity of that city.

Dr. Hering was the author of several technical books, and the recipient of the honorary degree of Doctor of Science from the University of Pennsylvania. He belonged to the American Society of Civil Engineers, the Canadian Society of Civil Engineers, the Institution of Civil Engineers, The Franklin Institute, the American Water Works Association, the New England Water Works Association and the American Public Health Association, and was a Fellow of the American Academy of Science. He became a member of The American Society of Mechanical Engineers in 1906.

Engineering Achievements of Pacific Coast Shape Program for Regional Meeting

Los Angeles Headquarters for Second A.S.M.E. Regional Gathering—California's Remarkable Progress in Engineering Described in Addresses and Viewed on Excursions

THE SECOND A.S.M.E. regional meeting, held in Southern California April 16–18, 1923, under the auspices of the Los Angeles Local Section, matched its predecessor, at Springfield, in success. The Hotel Alexandria, Los Angeles, was headquarters for the meeting and there, on the opening day, the first and only session designated as technical was held. After that the program demonstrated once again the fundamentally technical character of excursions which are opportunities for gathering scientific information rather than mere sightseeing expeditions.

An account of the technical session is given in succeeding columns. On the afternoon of April 16 an opportunity to study engineering work in the motion-picture industry was given in an address by Mr. Langey of the Pickford-Fairbanks studio, followed by an inspection of the studio in Hollywood.

On April 17 the meeting moved on to Pasadena where the morning was spent at the Norman Bridge Laboratory of Physics at the California Institute of Technology. Prof. E. C. Watson, who conducted the party about the laboratory, explained a number of interesting things, including the use of the special screen for vertical projection by showing the principles of wave motion as illustrated in a ripple tank; some slides of actual photographs of sound waves; the power of the circuits to the lecture room by means of an experiment on electromagnetic repulsion in which an aluminum ring was thrown to the ceiling; acoustics of the room as illustrated by sounds produced in large pipes by heat vibrations; some experiments with ultra-violet light, showing the peculiar fluorescence produced in many substances, etc.

Dome of 100-in. Hooker Reflecting Telescope, Mt. Wilson Observatory

The afternoon was spent at the laboratory and shops of the Mt. Wilson Observatory. One of the most interesting machines which the members were allowed to inspect was a ruling engine, perfected by one of the members of the staff, and representing many years of study. With this engine it is hoped that 100,000 lines to the lineal inch can be ruled. A sample of the work of the machine, carrying 15,000 lines ruled to the lineal inch, was an object of great interest.

Late in the afternoon the party motored to the top of Mt. Wilson, where the night was spent. In the evening Prof. Francis G. Pease, astronomer in charge of design at the observatory, gave details regarding the 100-in. Hooker reflecting telescope there installed, the most powerful instrument of its kind yet constructed. Extracts from his description are given later in this account. A heavy fog made impossible the demonstration of this and other instruments that evening, but early the next morning many of the party inspected the 150-ft. tower telescope used for studying the sun, and examined the powerful 75-ft. spectrograph.

By noon the engineers had reached Long Beach. Ralph Reed, chief engineer of the Union Oil Company, spoke briefly on oil-field tools and equipment, after which the oil fields of Santa Fe Springs and Signal Hill were visited.

A more detailed account of the excursions appeared in the May 7th *A.S.M.E. News*, and preceding issues carried descriptions of the engineering achievements at Mt. Wilson and other places visited by the engineers. Those who have had the opportunity to participate in such excursions where demonstrations and explanations are given and close inspection permitted can best appreciate their technical value.

Back in Los Angeles Wednesday evening the meeting closed with a banquet at the Hotel Alexandria, details of which are given on a following page.

Too much credit cannot be given to the committees in charge for the success of this regional meeting. The Regional Committee, Carl C. Thomas, chairman, and the Los Angeles Local Section Committee, George H. Rhodes, chairman, were assisted by committees on local arrangements, with chairmen as follows: finance, J. G. Rollow; professional events, G. H. Rhodes; printing and signs, H. L. Doolittle; entertainment, J. G. Rollow, excursions, Prof. R. L. Daugherty; hotels, H. R. Hilton; information and service bureau, H. L. Doolittle; publicity, R. W. Lawton; and reception, H. R. Hilton.

The Technical Papers and Addresses

Five papers were presented at the technical session held on Monday forenoon, namely, The Oil Venturi Meter, by E. S. Smith, Jr.; Flow of Crowds, by C. H. Benjamin; The Cross-Flow Impulse Turbine, by Forrest Nagler; Diesel-Engine Progress on the Pacific Coast, by H. W. Crozier, John Stigen, and C. E. Nagel; and Hydroelectric Development by the Southern California Edison Co., by H. A. Barre. The papers by Messrs. Smith and Nagler appeared in Mechanical Engineering for May, and the one by Messrs. Crozier, Stigen, and Nagel is printed in the present issue.

Dean Benjamin's paper dealt with the flow of crowds, which he likened to the flow of viscous liquids through pipes. The loss of energy by friction in passages, contracted openings, and bends was similar, and the absence of a pressure head was met by continuing muscular energy. The paper developed a simple formula for the flow. The constants used therein were determined by a series of experiments in a three-story college building with large rooms, halls, and stairways. The crowds (of students) were variously distributed and controlled, and the widths of doorways and stairways were adjustable. It was found that with normal men under control, moving as fast as practicable without crowding, about twice as many could descend stairways and pass through openings of a given width in a given time as had generally been estimated; but it did not follow from this that the old rule should be done away with, for crowds did not always comport themselves as well as those considered in the paper.

Mr. Barre, electrical engineer of the Southern California Edison Co., described the extensive program for power development now being carried out by that organization. This hydroelectric work is chiefly on the San Joaquin River, in the Big Creek district some 240 miles north of Los Angeles, where the conditions are such that it is possible to provide a complete coördinated scheme for the total utilization of the resources of that river—for irrigation as well as for power—in conjunction with the company's other water powers further south and the steam-plant resources which must necessarily accompany any water-power development. In the area under development about 1,400,000 hp. of commercial power is available, and the total cost of the new work involved will be in the neighborhood of $200,000,000. The development comprises two large tunnels, one 5 miles long and 21 ft. in diameter, and another 12 1/2 miles long and 15 ft. in diameter; and several storage reservoirs having capacities of 75,000 acre-feet and upward. When the development is completed the water will have been used through a total head of nearly 6000 ft.

On Tuesday morning, at the California Institute of Technology, Pasadena, R. W. Sorensen, professor of electrical engineering at that institution, described the million-volt 1000 kva. testing set to be installed in its new high-voltage laboratory. There was every reason to believe, he said, that potentials up to this value would be required in the very near future for the testing of standard apparatus used for electric power transmission, and in the meantime the set would be available for use in the investigation of high-voltage phenomena ahead of the commercial demand for high-tension apparatus. The Big Creek system of the Southern California Edison Co., described by Mr. Barre on Monday, had already raised their voltage from 150,000 to 220,000, thus doubling the amount of power they could transmit over their present lines, and many of the tests required by the 220,000-volt apparatus had called for testing potentials of from 450,000 to 500,000 volts. The transformer which Professor Sorensen had designed and which would shortly be installed would consist of four 250,000-volt units, each so constructed that one of its windings could be used to excite another transformer of the series. When the four 250,000-volt windings of these transformers were connected in series with one end grounded, a potential of 1,000,000 volts from line to ground would be obtained. This equipment would at the same time provide the laboratory with a 500,000-volt system with step-up and step-down transformers, four separate 250,000-volt testing sets, or, by use of three transformers Y-connected, a 433,000-volt three-phase transmission line to work with.

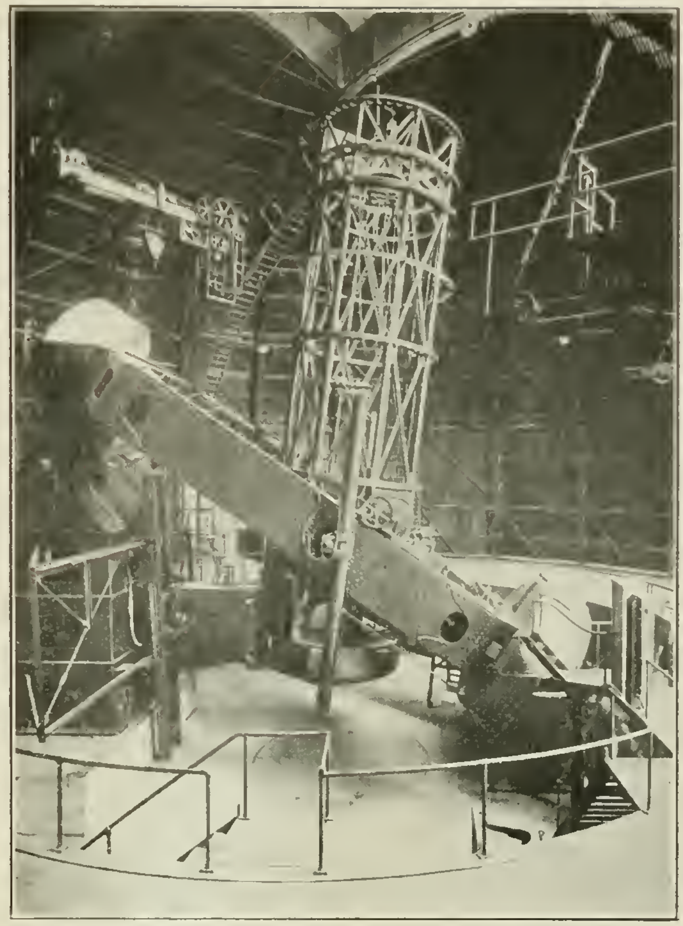
Extended extracts from the address by Professor Pease, referred to in a preceding paragraph, immediately follow.

The 100-Inch Hooker Reflecting Telescope of the Mount Wilson Observatory

The most powerful of all telescopes thus far constructed is the great Hooker telescope of the Mount Wilson Observatory, having a clear aperture of 100.4 in. and a primary focal length of 507.5 in. The telescope is now in actual use, the daily results proving the value of the instrument to be of the highest order.

The Hooker telescope is of the reflecting type wherein a parabolic mirror converges the parallel beam of light coming from the distant object to a focus. The image given is a real image, just as is given by a camera lens; it can be viewed with an eyepiece or photographed by placing a plate at the focal plane.

The mirror is 101.3 in. in diameter, 12 in. thick, and weighs 9000 lb. It is glass, cast in France by the St. Gobain works. Any internal strains likely to alter the curvature are eliminated by mounting the glass on large edge arcs supported on knife edges and supporting it horizontally on 12 pads, three of which are fixed, the remaining 9 counterweighted. The glass and its supporting systems lie in a massive steel cell which bolts to the lower end of an open tube 11 ft. outside diameter and 38 ft. long. The bottom section of the tube is composed of steel-casting rings, columns triangular in cross-section, of pressed-steel plates, and open panels of steel plate. Two massive castings are built into the section to carry the declination trunnions. The remaining sections, including the "cages" which carry the various auxiliary mirrors, are built of similar steel rings, columns of Shelby tube, corner castings of steel and diagonals of tire channel. Each section is assembled and then machined as a unit; the cages are interchangeable, fit a tapered ground point on the upper end of the permanent part of the tube and are locked in position by 8 lip bolts controlled by a single handle.



Interior View of Dome, Mt. Wilson Observatory

The weight of the tube is 35 tons; its center of gravity lies on the declination axis, so that it is always in balance. As some of the various attachments alter this balance, the change in moment is compensated for by the motion of two 1400-lb. weights in the large tubes at the side. Two additional counterweights are placed under the mirror cell to provide for adjustment about the axis of the tube.

The declination bearings are spherical in shape to allow for any flexure of tube or yoke; these spheres serve to align the axis while the bulk of the weight at each bearing is taken up by two systems of roller and ball bearings, one axial, the other radial; these systems are counterweighted by a series of levers extending downward along the yoke and actuated by a common weight.

The tube is suspended in a massive yoke, the polar axis, 16 ft. across and 32 ft. long, on the ends of which are trunnions supported by massive bearings. The axis of the yoke lies parallel to the earth's axis and is inclined at an angle of 34 deg. 13 min. to the horizontal, pointing to the north pole of the heavens.

The yoke consists of four members, built of structural steel with a massive steel casting at each end; their weight is 10 tons each and after assembling each was machined as a unit. Their average cross-section is 2 ft. wide by 4 ft. deep; hollow steel trunnions are bolted on the end members, and to these in turn are bolted the large steel flotation drums. The weight of the moving parts of the telescope is 100 tons. This mass is driven at just such a rate (1 revolution in 24 hours) as to equalize the diurnal motion of the earth, consequently every provision is made to reduce friction to a minimum. To define the polar axis there are two spherical bearings, and to relieve the friction two liquid flotation systems, consisting of hollow steel drums fastened to the trunnions, which float in tanks of mercury supported by the north and south pedestals. The drums are bolted at their upper ends and their insides relieved about an inch so that sleeves fastened to the south faces of the

tank reach nearly to the upper faces of the drums, thus increasing the depth by many inches. The south drum displaces 60 tons and the north 40 tons. There is a ball ring thrust bearing at the lower face of the south bearing to define the position of the axis longitudinally. The instrument is driven by a "driving clock" through a worm and worm wheel which clamps to the south trunnion.

Rapid motions are provided for setting the telescopes in right ascension and declination as well as slower motions to enable the observer to correct for errors in speed, refraction and bad seeing.

The worm wheel, which is 200.53 in. in diameter, has 1440 teeth accurately cut on the circumference and so ground that there is no periodic error as great as 0.00001 in.

The driving clock connects directly to the worm with a double Hooke's joint to eliminate any periodicity due to the worm and clock shaft not being truly adjusted. The speed of the worm can be altered by the observer by means of a motor mounted on the last shaft of the clock. The declination, quick, and slow motions are mounted on the yoke beside the tube and operate on it, the former through a sector, the latter through a long screw and arm. The range given by the two motions is from 30 deg. to $2^2/_3$ min. arc per minute of time.

The telescope stands on a hollow concrete pier 33 ft. high, bringing the intersection of the polar and declination axes at elevation 50 ft.

Since variation in temperature alters the figure of the mirror with consequent distortion of the image, the mirror and its cell have been surrounded with an inch of corkboard and means provided to control the temperatnre within the enclosure. Brine, the temperature of which is automatically controlled by a thermostat within the enclosure, is circnlated from a tank in the pier through coils lying under the mirror; fans circulate the air all around the mirror and coils. The brine is heated by electrical coils in the tank and cooled by ammonia expansion coils. Eight interconnected leaves, motor-operated, fold open in front of the mirror when in use.

The housing is a dome 100 ft. in diameter and 100 ft. high, all above 28 ft. rotating on tracks on the lower fixed part. The dome is of structural steel and sheathing throughout, and double-walled to insure more uniform temperature inside. The upper part is carried on 28 trucks with conical wheels and is traction-driven by two $7^1/_2$-kw. motors at opposite points. Its weight is 550 tons, while that of the fixed part is 250 tons. A slot 20 ft. wide extends from elevation 44 ft. to the peak of the dome, providing an opening through which the telescope is pointed, and is covered with a shutter formed by two halves moving along horizontal tracks.

To reach the primary focus of the telescope an observing platform is placed across the shutter opening, which travels up and down the main girders, its level being automatically regulated at the hoisting drum. To reach the secondary or Cassegrain focus on the north side of the tube, there is a platform which travels across and up and down the south face of the north column.

All motions of the instrument and dome are motor-driven and nearly all the circuits are "remote control." The settings can be made from a deck just beside the south pedestal and from auxiliary controls at the three foci. There are altogether 40 motors used in the dome, with an aggregate of 50 hp., and about 14 miles of wiring.

A 10-ton crane travels along the main girder opposite the shutter opening and handles all cages and instruments about the telescope.

The telescope is situated upon Mount Wilson near Pasadena, California, 5800 feet above sea level, where the atmosphere is free from the lower clouds and dust and where it can be operated a large part of the year to excellent advantage.

Looked on as an engineering problem, no serious difficulty was met with in the construction of the Hooker telescope, and a machine of double the aperture might well be built before one was seriously at the limiting factors of the materials of today.

Speakers at the Banquet

The banquet with which the regional meeting closed gave those attending it an opportunity to meet and hear speak a number of the men who have done much to advance the engineering profession, either in California or other sections of the country. Carl C. Thomas, as chairman of the Committee on Arrangements, made the address of welcome and introduced the toastmaster of the evening, John A. Britton, first vice-president and general manager of the Pacific Gas & Elec. Co., of San Francisco.

The welcome of the city of Los Angeles to the Society and its guests was expressed by Captain John D. Fredericks, past-president of the Chamber of Commerce of Los Angeles, and C. E. Cook, now head of its publicity department. Captain Fredericks, an eloquent speaker, voiced the praise and love of many for the Pacific Coast. "Out here," he said, "where the Pacific has been singing the sunset song of the nation for a great many years, we have learned that it is a wonderful place to live and a wonderful place to dream; but we have also learned that it is a wonderful place to work." He called attention to some of the great engineering feats that have been accomplished and some yet to come. He referred particularly to the protection of the Imperial Valley from the flow of the Colorado, and to the reclamation of some two million acres of unproductive land lying just back of it, and to the building of a great harbor for Los Angeles.

Mr. Cook, who personally conducted the first excursion of the A.S.M.E. to California, back in 1892, described that trip and similar ones, for other groups.

John Lyle Harrington, president of the Society, spoke of the difficulties which engineers have had to overcome in developing California and urged that the strength, the knowledge, experience, and idealism which have been gained thereby be contributed in ever greater measure to the upbuilding of a unified engineering profession. He urged also that the engineer participate more largely in the business and government of the country, stating emphatically that "it is highly essential that the engineer come to take more than a technical part in the work of the development of the nation."

Dr. Ira N. Hollis, past-president of the Society, who recently resigned the presidency of Worcester Polytechnic Institute, a follower for many years of the sea, used a number of his stock of sea stories to drive home the importance of the solidarity of the engineering profession. He spoke briefly of the ties which bind the states of the Union together and praised the engineer for the part he has played in establishing these ties, and for his achievements in other countries, particularly in Egypt. He disagreed with those who feel that the engineers are praising their profession too much, because "it is pride in our profession that will enable us to do the best work."

The growth of the manufacturing industries of Los Angeles was surveyed by Henry M. Robinson, president of the First National Bank of Los Angeles. He believed that her possibilities as a point for assembling raw materials for manufacturing and distribution to the Atlantic seaboard cities were very great. He referred specifically to cotton, copper, pig iron, and steel.

R. H. Ballard, vice-president and general manager of the Southern California Edison Co., pictured what prosperous public utilities mean to communities, and discussed the share of the communities in making their utilities prosper. "The prosperity of any section," he said, "depends upon having a good, active, energetic, and prosperous public utility or a number of utilities." He discussed the ownership and regulation of public utilities, pointing to the advantages of private ownership with public support, the method now in general practice.

William Mulholland, chief engineer of the Bureau of Water Works and Supply of Los Angeles, spoke of the responsibility of the engineering profession as an agency in the advancement of man. "Every step in the progress of man," Mr. Mulholland said, "is marked by his ability as an engineer. All the implements or early instruments that go back to the earliest history of mankind, are evidences of his ability as an engineer. The advancement of man parallels the development of tools."

D. W. Pontius, vice-president and general manager of the Pacific Elec. Ry. Co., spoke briefly on interurban transportation. He discussed the enormous amount of traffic in California and the steps being taken to handle increasing traffic in the future.

The final speaker, Dr. Robert Sibley, who for years has closely followed hydroelectric developments, particularly on the Pacific Coast, gave an illustrated lecture on the subject, which was of great interest to his listeners. It is planned to publish his address in the August issue of Mechanical Engineering.

Fluctuations in Student Enrollment in Engineering Courses

Data Furnished by Twenty-One Typical American Universities and Colleges Show Trends in Interest in Engineering Education During Past Ten Years

MANY engineers and educators are of the opinion that the interest in engineering as a profession varies with the commercial prosperity as well as with the normal growth of the country. Educators have reached the conclusion that the scholastic mortality of engineering students is high. The first of the above conditions would appear to be a natural sequence of human events; the second would indicate an error in choice by the student, a lack of sufficient and sound preparation, or a faulty program.

In order to determine conditions and trends in interest in engineering and in the mortality in engineering courses, comprehensive enrollment figures of engineering students in twenty-one American colleges, universities, and institutes have been secured, the institutions being selected with due respect to geographical distribution. The data were collected and this report prepared by Alan Bright and W. F. Rittman, registrar and professor of commercial engineering, respectively, of the Carnegie Institute of Technology.

Fig. 1 (*a*) shows the numbers and changes in total enrollment of engineering students in the twenty-one institutions under consideration. It is frankly recognized that these total numbers fall far short of the total enrollment of students in engineering in America. It is believed, however, that the trend is definitely in harmony with that of the entire country. The curve clearly shows that during the world war and immediately following, the number of engineering students increased at a rate unprecedented theretofore and reached a maximum in 1920. The 1920 enrollment is nearly 80 per cent greater than the somewhat constant registration existing in 1913 and 1914.

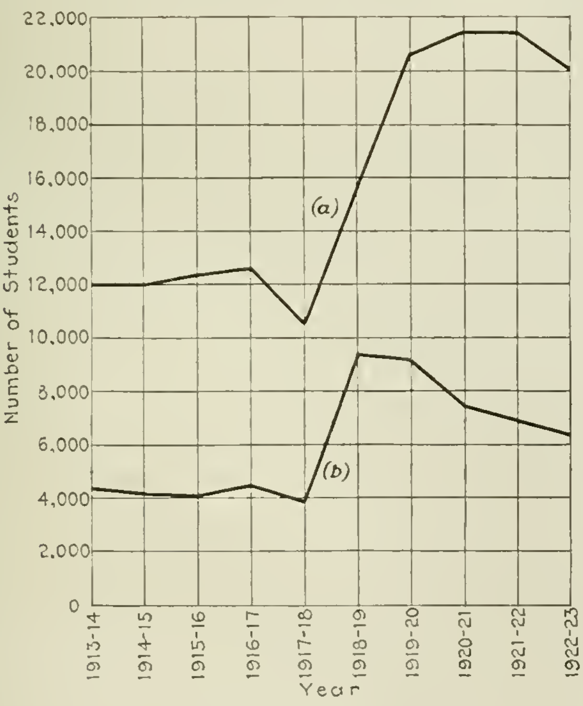


Fig. 1 Total Enrollment (*a*) of All Students and (*b*) Freshmen in 21 Engineering Schools, 1913–1922

Fig. 1 (*b*) shows the numbers and changes in freshman enrollment of engineering students of the institutions. It is believed that this curve shows the attitude and changes in attitude of the general public toward engineering as a profession. The world war appears to have given a tremendous impetus to public interest in the study of engineering. This impetus is very probably the result of the fact that modern warfare is almost entirely a matter of applied engineering in all its branches. Never in the history of the world were engineers of greater importance and in greater demand than during the period from 1915 to 1920. The dropping off in the enrollment of freshman engineering students from 1919 to 1922 was but a natural reaction from the abnormal increase of 1918 and 1919, aided by the industrial depression of 1920 to 1922. Added to these conditions there was a decreased demand for engineers. These figures, also, are not absolute totals for the country, but it seems evident that they do definitely represent trends.

Fig. 2, expressed in terms of percentage, show the ratio of engineering freshmen to seniors. These percentages vary from as high as approximately 80 per cent to as low as approximately 20 per cent of those who enter as freshmen and who remain until their senior year.

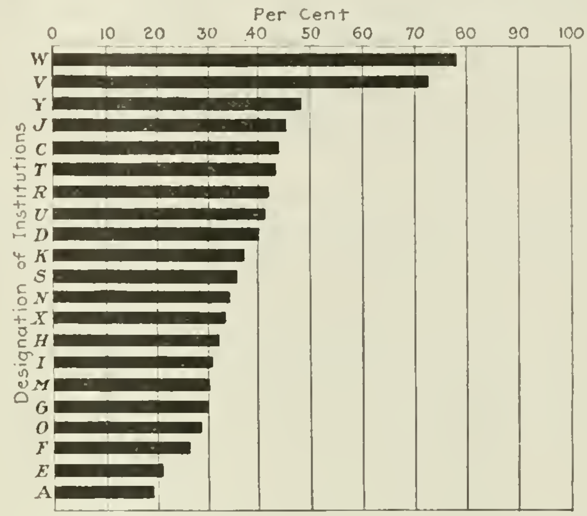


Fig. 2 Ratio (expressed in percentage) of Seniors to Freshmen in 21 Engineering Schools, 1913–1922

Certain institutions receive a large percentage of their upper-class students from the academic colleges who register with advanced standing. As a matter of economy many students, especially in the Middle West, prefer to attend an institution near home for one or two years and then enter a more distant engineering school, even at the expense of spending five years in college. It is not infrequent that heads of engineering schools urge those who can afford it to graduate from an academic college before entering an engineering school. This tendency accounts for the lower mortality in the upper years at certain institutions.

TABLE 1 AVERAGE CLASS ENROLLMENT IN ENGINEERING COURSES IN 21 TYPICAL INSTITUTIONS, 1913–1922

Institution	Freshmen	Sophomores	Juniors	Seniors
W	525	504	471	412
V	157	141	131	114
Y	222	163	128	108
J	298	228	178	136
C	351	245	211	156
T	310	207	157	136
R	224	136	111	99
U	187	134	105	80
D	120	81	60	48
K	551	365	253	205
S	231	163	107	85
N	396	307	199	138
X	161	99	75	56
H	173	87	56	58
I	582	258	233	180
M	370	251	163	112
G	143	80	53	43
O	320	189	115	93
F	304	187	103	81
E	173	108	57	37
A	270	139	82	53
Average	289	191	145	117

Table 1 gives the average number of students, during the years 1913–22, in each of the 21 institutions under observation, and the averages for them all, from which the percentages of loss may be easily computed.

Meetings of Other Societies

American Institute of Electrical Engineers

The operation, control, and protection of transmission and distribution systems was selected this year by the American Institute of Electrical Engineers as the keynote of its spring convention, held in Pittsburgh, Pa., April 24–26, 1923. Of the five technical sessions, including in all some twenty papers and a good deal of valuable discussion, one on the morning of the second day of the convention held the greatest interest for mechanical engineers.

Three of the papers at this session dealt with electric-furnace problems. F. V. Andreae, chief engineer for the Southern Manganese Corpn., Anniston, Ala., stated his belief, formed after careful observation of electric-furnace operation, that the transformation of electrical energy into heat energy in the furnace takes place in an arc passing through an atmosphere of vapors under pressure. He derived a general equation for the three-phase furnace and took up specific examples of its application, showing how the unbalance can be taken care of in several ways. His final conclusion was that the general performance of the three-phase furnace can be determined in advance with a high degree of accuracy by using the simple equations of the balanced three-phase system, where the only thing that is necessary is the previously determined reactance per phase.

A paper by Frank Hodson, president of the Electric Furnace Construction Co., dealt with the development of the large electric melting furnace, the limitations of large electrode furnaces, and the design and construction of the 80-ton furnace at the Ford River Rouge Plant. The advantages of correct heat application, the influence of the new Soderberg continuous electrode on furnace design, and the possibility of using large electric furnaces as an intermediate process for the manufacture of cheap steel were other subjects discussed by Mr. Hodson. The new Soderberg electrode to which he referred consists of a thin metallic casing the size of the electrode to be used, into which the electrode paste or mix is dropped. The actual baking of the electrode is done in the furnace.

The other paper on electric furnaces was by A. N. Anderson and B. D. Saklatwalla, both of the Vanadium Steel Corpn. It discussed electrical factors to be considered in the design of leads for ferroalloy electric furnaces in order to achieve the highest input efficiency.

At the same session A. H. Babcock, electrical engineer for the Southern Pacific Railroad, presented a paper on Some Fuel Determinations on the Southern Pacific System, and C. T. Guildford, of the Westinghouse Elec. & Mfg. Co., one on Heating a Cotton Weave Shed by Electricity. Mr. Babcock gave test data on a representative mountain railway on the West Coast showing the fuel consumption of an average mountain-type locomotive burning oil, beginning with firing up at the engine house and including consumption while testing brakes, during acceleration, running up and down various grades, holding the trains on sidings, and finally running down hill over stretches of steep grade. The overall efficiency determined by the test was 5.57 per cent, but the author stated that the data apply only to the specific conditions and should not be applied indiscriminately to all conditions of operation.

Mr. Guildford described the electric heating system at the St. Croix mill of the Canadian Cottons Co., Ltd., Milltown, New Brunswick, Canada, which operates nearly 57,000 spindles and over 1400 looms, and told how to estimate the quantity of heat required for such buildings. The method of heating employed at the St. Croix mill is the Sturtevant hot-air system with groups of electric heating units instead of steam coils in the fan room. The weave shed, which is a one-story building 480 ft. long by 180 ft. wide, requires 1600 kw. consumption at 15 deg. below zero. Electric heat may be adopted with economy in mills where surplus hydroelectric power is available. To be on a parity with coal at $10.50 per ton, the electric heat should cost $0.0025 per kw-hr. where the average heating-season temperature is 22 deg. In the case of the plant at Milltown a return of more than 37 per cent on the investment for the electrical equipment is shown.

Subjects discussed at other sessions of the convention were grounding devices, the technical features of surges and arcing grounds, relay schemes and illumination, reactors, lightning disturbance, and insulators.

American Welding Society

A comprehensive program, reviewing progress in all the phases of welding, was presented at the annual meeting of the American Welding Society, held in New York, April 24 to 27. The majority of the sessions were devoted to committee reports, only two including the presentation of papers.

Four speakers summarized new developments in the welding field, as follows: W. L. Warner, General Electric Co., Schenectady, N. Y., Electric Welding; G. O. Carter, consulting engineer, Linde Air Products Co., New York, Gas Welding; Hermann Lemp, General Electric Co., Erie Pa., Resistance Welding; and J. H. Deppeler, chief engineer, Metal & Thermit Corpn., Jersey City, N. J., Thermit Welding.

Mr. Warner reviewed the work of the American Bureau of Welding, which is the welding research department of the American Welding Society. Standard tests for welds and welding-wire specifications have been made and a large amount of general research work carried on. Enumerating some interesting applications of the welding process, Mr. Warner spoke of hammer forging as being highly valued for improving the strength, ductility, and fatigue resistance of metal deposited by the electric arc. High welding currents are now being used, he stated, 300 amperes sometimes being employed with coated electrodes for large thermal capacities, and the arc welding of brass with a flux-covered type of copper electrode is already commercial in England. Malleable-iron welds, although possible and sometimes necessary, are not sufficiently strong to justify frequent use. Mr. Warner stated that arc welding has been found economical for the repair of machinery in steel mills, and that the arc welding of monel metal is possible when the proper reducing flux is used. Referring to arc-welding apparatus, the speaker described a safety switch which cuts the power from the welding line and primary circuit whenever the arc is not being drawn. The voltage at all times during welding is limited to a harmless value.

The welding of long stretches of steel pipe was emphasized as an outstanding feature of the past year by Mr. Carter, who gave details of a 140-mile line of 8-in. pipe welded by the Prairie Pipe Line Co. There are three intermediate pumping stations and the line has been welded into a continuous tube from one station to the other, no coupling joints being used. The line carries 750 lb. maximum oil pressure. Mr. Carter suggested the welding of the barrels of concrete mixing machines instead of the usual riveted instruction, outlined the further extension of oxy-acetylene welding to maintenance and repair work, and reported that many valuable applications of the oxy-acetylene process of cutting cast iron have been made. The correct methods of handling cast-iron welding, however, are not so well known.

Mr. Lemp, outlining developments in resistance welding, said that the progress has been made in extending the application of the process with existing apparatus. Among the newer applications which he mentioned were the successful welding of the halves of steel castings and forgings, the welding of cast-iron valve heads to steel shanks, and the welding of tungsten and copper cable for radio apparatus.

The fourth speaker, Mr. Deppeler, gave the results of a research to eliminate blowholes in steel, which is accomplished by permitting the gases to escape through the molds. He also spoke of developments in the rail-welding field and described a new and more efficient design of preheater recently developed.

At a second technical session Dr. H. L. Whittemore, of the Bureau of Standards, Washington, D. C., outlined the method and results of tests made by the Bureau on unfired pressure vessels. These tests were conducted in coöperation with the pressure vessel committee of the American Bureau of Welding for the information of the A.S.M.E. Boiler Code Committee, which is now working upon a code for the construction of unfired pressure vessels. A hydrostatic and hammer test was used and 40 tanks have been tested to the point of destruction. The shells of most of the tanks were 6 ft. long by 2 ft. in diameter and made of $^3/_8$-in. mild-steel plate. Both electric and oxy-acetylene welding were used. It was found that the welded pressure vessel, according to the regular formula for working pressure, has a factor of safety of about 6. The results of the tests are now in the hands of the Boiler Code Committee.

At the same session J. C. Wright, of the Federal Board of Vocational Training, chairman of the committee on training of welding

operators of the American Bureau of Welding, explained a training course for oxy-acetylene welders developed by his committee. The analysis of the work of an oxy-acetylene or gas welder presents various types of jobs with a statement of the operations necessary to perform each, and the information and skill which the operator must possess in order to be an efficient worker.

American Foundrymen's Association

For the third time in its history the American Foundrymen's Association selected Cleveland for its annual convention. The first of its meetings there, which was also the occasion of its first official exhibition of foundry equipment and supplies, took place in 1906; the second occurred ten years later; and the third, which was the 27th annual meeting, in conjunction with the 17th exposition, was held April 28 to May 4, inclusive.

A commendable feature of the technical program was the great reduction in the number of papers presented, as compared with previous conventions, permitting more extensive discussion and promptness in closing sessions. The business session was brief. The election of G. H. Clamer as president to succeed C. R. Messinger was announced. Mr. Clamer is first vice-president and general manager of the Ajax Metal Co., Philadelphia, and is well known not only for his work as a non-ferrous metallurgist but also for his investigations of alloys and inventive work in connection with electric furnaces. Mr. Messinger, the retiring president, Dr. George K. Burgess, newly appointed director of the Bureau of Standards, and Dr. H. Ries, of Cornell University, were elected honorary members of the association in recognition of their services to it.

There were two joint sessions with the Institute of Metals Division of the American Institute of Mining and Metallurgical Engineers, both on the subject of non-ferrous foundry practice. A feature of the first, held on April 30, was the presentation of the annual exchange paper from the Association Technique de Fonderie. In the absence of the author, M. de Fleury, Mr. Clamer read the paper, which was on the application of the aluminum alloy alpax in the foundry. Alpax was described as being an alloy of aluminum and silicon which when treated with certain alkaline salts is said to have unusual properties. Because of its lightness, strength, and low coefficient of expansion and contraction it has been developed for automotive parts particularly, being used for cylinders, pistons, and connecting rods. Other properties and uses of the alloy were also discussed. Emile Ramas, president of the Association Technique de Fonderie and director of the Société Francaise Metallurgique, was a guest at this session and spoke briefly.

R. J. Anderson, of the U. S. Bureau of Mines, Pittsburgh, Pa., was another prominent figure at these joint sessions. At the first he presented a paper on the linear contraction and shrinkage of light aluminum alloys, giving results of a series of experiments at the Bureau to obtain data for use in making pattern allowances. The linear contraction was found to vary between 0.95 and 1.80 per cent. He was also co-author of two papers presented at the second joint session. One gave additional data secured by the Bureau of Mines, dealing with the linear contraction of brasses and bronzes, showing that in general high-temperature pouring causes less contraction than low-temperature pouring. The other discussed the effect of heat treatment on release of stress in bronze castings. E. G. Fahlman, National Smelting Co., Cleveland, and C. L. Eldridge, Metropolitan Museum of Art, New York, were respectively co-authors of these papers.

Among other papers presented at this session was one by F. L. Wolf and W. Romanoff, Ohio Brass Co., Mansfield, Ohio, abstracted by Dr. Paul D. Merica, International Nickel Co., New York. It discussed various shop problems encountered in making castings of brass and bronze, and gave data on pouring temperatures, furnaces, properties of castings, fluxes, etc. It was concluded that the pouring temperature should be as low as possible, consistent with the sizes of the castings.

There were also two sessions on steel foundry practice. Major Minton, U. S. Ordnance Dept., Watertown Arsenal, Watertown, Mass., dealt with the production of links and grousers for army tractors. The physical and chemical properties which these castings must have was given and their heat treatment described. Slides depicted the method in use at the Watertown Arsenal for testing these castings.

A paper illustrated by slides and a motion picture showed a process for the centrifugal casting of steel developed by William McConway, of McConway & Torley, Pittsburgh, Pa. The paper was presented by Harvey Allen of the McConway company. The steel is cast, revolved under hydraulic pressure until it is solidified, conveyed to the soaking pit, and then broken down on the forging presses to produce various sections.

H. A. Lorenz, Bucyrus Co., South Milwaukee, Wis., brought out the fact that the heat treatment of steel castings emphasizes the good and bad qualities of the original casting. He mentioned particularly the bad effects of non-metallic inclusions, dendritic structure, and improper density. He presented data on heat-treating practice on chrome-nickel-steel castings and recommended further research on special alloy steels.

An investigation to determine specifically the proper thermal treatment to apply to electric steel castings of 0.20 to 0.32 per cent carbon was described by H. A. Neel, Michigan Steel Casting Co., Detroit, Mich.

Several papers on gray iron were presented, one of particular interest to mechanical engineers being on gray iron for automotive castings, by H. B. Swan, Cadillac Motor Car Co., Detroit. It contained the results of a questionnaire sent to twenty-five automotive-castings plants, giving data on iron mixtures and cupola practice in producing cylinders, pistons, crankcases, and various small castings. The author reviewed the effects of carbon and other elements upon the physical properties of automotive castings, and commented upon the lack of standard cupola practice and of tuyere ratios.

At a session on malleables a paper by E. D. Smith, Lakeside Malleable Co., Racine, Wis., read by E. J. Lowry, of Hickman, Williams & Co., Chicago, showed that there are great possibilities in hardening and tempering malleable castings. It described experiments conducted to determine the feasibility of hardening malleable-iron parts, the nature of the hardened product and the processes best adapted to hardening, and suggested further fields for research on this subject.

Other papers at this session dealt with the application of fuel oil to the malleable air furnace, describing furnace construction and methods of operation which have been successful; the adaptation of continuous tunnel annealing furnaces to the malleable-iron industry, with details as to the construction, operation, and control of the furnaces; and a method for reducing the amount of scrap in a malleable foundry.

Two sessions on sand research, reclamation, conservation, testing methods, and geological survey work were of great interest to members interested in these phases of foundry work. Several committees reported, bringing out considerable discussion, and a number of papers were presented. Much of the discussion centered about methods of determining the bonding strength of molding sands. Dr. Ries described experiments at Cornell based on the Doty method, but with a different process of ramming the sand specimen.

Industrial engineering, dealing principally with employment, cost accounting, foreman training, compensation, and apprentice ship courses, has in recent years received considerable attention at the foundrymen's meetings. This year the subject of industrial education was presented for discussion in the form of a symposium of eleven papers on training foundry workers. The speakers represented not only state and educational institutions but also manufacturers who have inaugurated foundry courses. It was the consensus of opinion that the successful apprentice course must be based on a policy to give thorough training to the apprentice, and at the same time afford a sufficient monetary reward during the period of apprenticeship.

Two sessions characterized as dealing with new developments in the foundry industry complete the technical sessions. Leon Cammen, associate editor of Mechanical Engineering, traced the history of centrifugal casting and outlined its possibilities. He explained the mechanics of centrifugal casting on horizontal, vertical and inclined axes respectively, and touched upon the temperature of mold surfaces, comparing warm molds, water-cooled, and hot molds. The process of hot-mold centrifugal casting, which he himself has devised, he said makes possible the production of thin sections $^3/_{16}$ in. and up in considerable lengths

and in comparatively small diameters. Heating the mold to a high temperature obviates the rapid chilling of metals that results when they are poured at temperatures only a little above the melting point. It has been found that a $^3/_{16}$-in. wall of steel poured against a mold having a temperature of 1700 or 1800 deg. fahr. takes about 45 sec. to harden completely, which is sufficient to produce clean metal. Becket metal analyzing 0.50 per cent carbon, 26 to 28 per cent chromium, 0.40 to 0.60 per cent silicon, and 0.60 per cent manganese is most suitable for the hot molds, and for best results the surface of the mold should be lapped as smooth as glass.

Dr. Richard Moldenke, Watchung, N. J., presented a paper at each of these sessions, one on the desulphurization of cast iron, in which he discussed various methods for reducing the sulphur content of iron, and one on the development of a new long-life mold. G. K. Elliott, The Lunkenheimer Co., Cincinnati, spoke on gray cast iron from the point of view of the electric furnace, outlining the main features of the acid and basic electric furnaces and then sketching the general operating features of both the cupola and the electric furnace. The manufacture of synthetic foundry iron in the electric furnace was discussed in a paper by C. E. Sims, C. E. Williams, and B. M. Larsen, all of the Northwest Experiment Station of the U. S. Bureau of Mines, at Seattle, Wash. They described the production of cast iron from almost any kind of ferrous scrap by the use of a carburizer. They recommended a dense, pure form of carbon for the carburizer and stated that this should be charged under the metal and the melting conducted from the bottom up.

Recent developments in British foundry practice were summarized in a paper by Dr. Percy Longmuir, director of research for the Institution of British Foundrymen. This paper was the annual international exchange paper contributed by the British foundrymen and may be characterized as supplementary to addresses by Dr. Longmuir before the A. F. A. over twenty years ago, in which he declared that the future of all foundry work depended upon the development of scientific methods. His paper, read by Mr. McPherran of the Allis-Chalmers Mfg. Co., showed how the growing use of such methods is making the British foundrymen more efficient.

An extensive exhibit of foundry supplies and accessories was held simultaneously with the convention at the new Auditorium. This exhibit deservedly attracted the attention of the foundrymen present, and was of considerable interest in many ways. While it did not show any striking new developments or sensational improvements in machinery, it went along way toward proving the high state of the development of the mechanical accessories now at the service of the American foundryman.

There were numerous exhibits of material-handling equipment, the demand for which is rapidly growing with the increasing scarcity of labor, as well as of sand mixers, molding machines, crucibles, welding apparatus, heating and small melting furnaces, etc.

American Electrochemical Society

The annual spring meeting of the American Electrochemical Society was held in New York, May 3 to 5, 1923, under the auspices of the New York section. A symposium on the production and use of rare metals was the main feature of the convention. Dr. F. M. Becket, Carbide & Carbon Co., New York, who secured the contributions, was presiding officer and opened the meeting with an address on an investigation conducted by the research department of his company under his direction to determine the effect of zirconium in steel. It presented some revolutionary facts, made public for the first time, showing the definite effects of the use of a silicon-zirconium alloy in the production of steels of various kinds, among which may be mentioned its scavenging and desulphurizing properties, as well as a remarkable effect which it has on the rolling properties of steel when the actual sulphur content is high.

One of the important papers of this symposium was descriptive of experiments with rare-metal steels using uranium, boron, titanium, zirconium, cerium, and molybdenum, by Dr. H. W. Gillett and E. L. Mack, of the Bureau of Mines, Ithaca, N. Y. A large protion of the paper was devoted to a discussion of molybdenum in steel. Molybdenum was said to be a real alloying element and more potent in its effect than any other element, except possibly carbon. Attention was called to the air-hardening properties, particularly the depth thereof, which molybdenum bestows upon steel, and to the changes which it brings about in the critical range, an effect which vanadium does not have. Dr. Gillett, who presented the paper in abstract, stated as his belief that the presence of molybdenum in steel results in good strength combined with extra good ductility.

The present status of the production of rarer metals, the effect of alloying elements in steel, the preparation of metallic uranium, and platinum metals were other subjects included in the symposium.

Miscellaneous subjects were covered at other sessions, among them being heat-insulating materials for electrically heated apparatus, methods of handling materials in the electric furnace and the best type of furnace to use, electric-furnace detinning and production of synthetic gray iron from tin-plate scrap, and a new process called "chromizing," analogous to calorizing and sherardizing. F. C. Kelly, who is connected with the research laboratory of the General Electric Co. at Schenectady, N. Y., described this process, which involves the introduction of chromium at temperatures above the ordinary into the surface of iron, forming more or less of a superficial alloy or covering. He stated that chromizing may be used to prevent the flow of a metal like copper on iron at a temperature above the melting point of copper, as well as to prevent corrosion.

Important to A.S.M.E. Members Interested in Stress Analysis

At the 1922 Annual Meeting, under the auspices of the Railroad Division, an extremely valuable paper dealing with stresses in locomotive frames was presented by R. Eksergian. The paper gives a lengthy and complete discussion of the analytical methods to be followed in determining stresses in locomotive frames.

In view of the fact that there was a great wealth of material presented at the last Annual Meeting and that the Committee on Publication and Papers was compelled to reduce the size of Transactions to the minimum, it was decided to omit Mr. Eksergian's paper from the annual volume, but to print pamphlet copies of the complete paper with the discussion on it, and supply copies to members who might desire to have them. The number of copies printed will be limited to the number of requests for it received before September 1. Requests for this pamphlet should therefore be sent to the Secretary's office before that date.

A synopsis of the paper follows. Members of the Society are requested to study this carefully and determine whether the subject-matter would be of value in their work. It may be stated that the analytical methods developed by Mr. Eksergian should prove of value to all engineers engaged in the study of stresses howsoever set up.

Synopsis of R. Eksergian's Paper on Stresses in Locomotive Frames

This paper is essentially a preliminary analysis of the major reactions brought on a locomotive frame, as well as of the nature of frame action as regards variation of bending moment, shear, etc., for differently supported types of frames.

A careful analysis has therefore been made of the various methods of equalization, spring design, and the nature of cab supports in electric locomotives. This is followed by a section dealing with the dynamics of the steam locomotive, where the variation of torque and a quantitative investigation of the various oscillations are discussed in detail. Further, a careful analysis of the variation of side-rod loads and journal-bearing loads is included. The succeeding section deals with electric-locomotive drives and the major reactions brought on the frame. This section includes the dynamics of the electric side-rod drive, which discussion augments the previous one on side-rod loads in steam locomotives. The next section discusses the dynamics of braking, its change in load on the equalization, and the reactions brought on the frame. In this section is included a brief discussion of bumping loads and dynamical loads on the drawbar.

For a more quantitative investigation of the effects of vertical loads the bar frame has been approximately treated as a continuous beam under equalizer-applied loads and boiler supports, and the variations of bending shear, etc., for the U. S. Standard Pacific locomotive are computed in detail in Appendix No. 1. Following this is a careful analysis of the stresses resulting from longitudinal loads due to traction, etc.

Finally, the nature of the lateral reactions and the dynamics of lateral oscillations on entering a curve, etc., are discussed, a short recapitulation of the static reactions while on a curve being also given.

A brief outline of methods of analysis coördinating with future experimental work is discussed in Appendix No. 2

Engineering and Industrial Standardization

The Lumber-Standardization Program

AT THE first American Lumber Congress, in 1919, steps were taken to inaugurate simplification and general standardization of lumber sizes and grades. Since that time the Engineering Bureau and the Bureau of Lumber Economics of the National Lumber Manufacturers Association, at the request of the American Lumber Congress, have been continuously engaged in a thorough study of lumber standards.

The lumbermen of the United States have assumed the responsibility of establishing and maintaining the lumber trade upon a high plane of efficiency and of ethical practice, and to accomplish this they have established the "Central Committee on Lumber Standards," representing the entire organized trade from producer to consumer and created by a general conference of lumber manufacturers, distributors, and consumers in July, 1922. This Central Committee on Lumber Standards is composed of

John W. Blodgett, *Chairman*, representing National Lumber Manufacturers Association
W. E. Hawley, *Vice-Chairman*, representing the Association of Railway Executives, and the construction engineers
John H. Kirby, representing the Southern Pine Association
Chas. A. Goodman, representing lumber manufacturers
Dwight Hinckley, representing American Wholesale Lumber Association
John E. Lloyd, National Retail Lumber Dealers Association, representing lumber retailers
Sullivan W. Jones, representing the American Institute of Architects
W. L. Saunders, representing lumber manufacturers.

Its declared function is to act as a steering organization to draft and submit to its constituent associations its best judgment of suitable ways and means to accomplish in practice the simplification of lumber grades; the standardization of lumber sizes, the certification of quantity and quality, and the enforcement, by means of association inspection service and, if practicable, by grade marking of definite standards of lumber sizes and grades.

The National Lumber Manufacturers Association with which, prior to the appointment of the Central Committee, the initiative in further development of the standardization program had been lodged by the lumber trade, turned over to the Committee the results of its three-year investigation of lumber standards, together with an outline of definite proposals for the Committee's consideration. These were made the basis of the suggestions for lumber standards now being submitted by the Committee to the lumber industry.

One of the first acts of the Central Committee was to arrange for the establishment and maintenance of permanent headquarters and offices in Washington, D. C., under the direct charge of R. C. Merritt, who it appointed to be its executive secretary. Its next important act was the creation of the following Consulting Committee to prepare in behalf of its constituents appropriate data and suggestions for the consideration of the Central Committee:

Wilson Compton, *Chairman*, National Lumber Manufacturers Association

Group Chairmen

George Gerlinger, representing manufacturers
W. T. Murray, representing manufacturers
Harry J. Meyers, representing retailers, Brown-Borhek Lumber & Coal Co.
C. V. McCreight, representing wholesalers, Ricks-McCreight Lumber Co.
C. E. Lindsay, representing railroads, New York Central Lines
Wm. A. Babbitt, representing wood-using industries, National Association of Wood Turners, Inc.
E. S. Hall, representing architects and general contractors, American institute of Architects
Dr. Hermann von Schrenk, representing engineering and technical organizations
A. W. Newton, representing engineering and other technical organizations.

Other Members

Guy Gray, representing retailers, Gray Lumber Company
Adolph Pfund, representing retailers, National Retail Lumber Dealers Assn.
Charles Hill, representing manufacturers, A. C. Tuxbury Lumber Company
L. Germain, Jr., representing wholesalers
John Foley, representing railroads, Pennsylvania Railroad System
E. A. Frink, representing railroads
Henry Ericsson, representing general contractors
Arthur E. Lane, representing American Wholesale Lumber Association
E. J. Curtis, representing wood-using industries
R. E. Brown, representing the Society of Automotive Engineers
J. M. Pritchard, representing Hardwood Manufacturers Institute.

As a result of one of the important decisions of a recent meeting, Mr. Compton, as chairman, will assign to individuals and groups of individuals, selected from the membership of the Consulting Committee, various phases of the problem of lumber standardization and simplification for investigation and recommendation. Their findings will be reported to the whole Consulting Committee.

Although conclusions regarding standardization in lumber-grading nomenclature and the marking of standard grades on lumber must necessarily await conclusions on grade standardization, they are now a subject for the consideration of the Consulting Committee. Grade marking can be undertaken on the present grades without awaiting conclusion of more uniform standards. Similarly improved and more uniform inspection service is closely related to grade standardization. These are, however, matters of immediate concern to lumber manufacturers and shippers and as a consequence may not require the consideration of the entire Consulting Committee.

The outline of immediate activities of the Consulting Committee includes careful consideration of the following:

1 Yard Lumber Sizes
2 Molding Patterns
3 Standard: (*a*) species; (*b*) use; (*c*) size; (*d*) manufacturing classifications of lumber.
4 The Forest Products Laboratory plan for investigation of softwood shop, and hardwood, lumber grading; and such consideration as the Consulting Committee may desire to give to the following:
5 Application to grading rules of Suggested Basic Rules for Grading Softwood Yard Lumber and Structural Timbers
6 Grade Marking
7 Use of Tally Cards
8 Inspection Service
9 Standard Names for Lumber Grades.

The suggested provision in lumber-grading rules for the admissibility of certain percentages of short lengths and odd lengths of lumber has been submitted to the constituent associations together with an analysis of information, and opinion thereon, prepared by the executive secretary.

Standardization in the Marine Field

THE general committee on Standardization recently formed by the American Marine Association has adopted a plan of organization which will enable it to establish standards in the marine field comparable with the work of similar organizations in other fields both here and abroad but entirely independent of them. The purpose of this movement is to give the marine industries of the United States the benefit of established and recognized standards for hull details and operation details. Both of these will reduce the cost of ship construction and operation and will thus help to place competition with foreign shipping on more equal terms.

The third meeting of the general committee was held in New York on April 17 with Captain R. D. Gatewood, U. S. N., as acting chairman. At this meeting it was resolved that the standardization and simplified-practice project in the marine field be carried on under the name of the "American Marine Standards Committee."

The purpose of the American Marine Standards Committee is in line with the movement inaugurated by Secretary Hoover of the Department of Commerce to eliminate waste and reduce costs. The extension of this work to the marine industries was proposed by him at the annual Marine Exposition in New York last Novem-

ber and was taken up by the American Marine Association with the support of the Department of Commerce and the United States Shipping Board Emergency Fleet Corporation.

In order to carry out the work expeditiously and economically, the committee has adopted a plan of organization in which the American Marine Standards Committee will act as the executive committee, all details and correspondence being carried out through the office of its secretary in the Division of Simplified Practice of the Department of Commerce in Washington.

The work of the organization will be administered primarily by three committees as follows:

A Organization, Membership and Finance
B Constitution and Rules
C Publicity and Relations.

The policies of these committees will be carried out by the secretary.

The following were appointed as members of the three administrative committees:

Committee A

Col. E. A. Simmons, *Chairman*, President, American Marine Association
Capt. C. A. McAllister, *Vice-Chairman*, Vice-President, American Bureau of Shipping
Charles F. Bailey, Engineering Director, Newport News Shipbuilding and Dry Dock Company
Hugo P. Frear, Naval Architect, Bethlehem Shipbuilding Corpn., Ltd.
E. H. Rigg, Naval Architect, New York Shipbuilding Corpn.

Committee B

William F. Gibbs, *Chairman*, President, Gibbs Brothers
E. H. Rigg, *Vice-Chairman*, Naval Architect, New York Shipbuilding Corpn.
Capt. John F. Milliken, Secretary, Neptune Association
John W. Gray, Newport News Shipbuilding and Dry Dock Company
Capt. C. A. McAllister, Vice-President, American Bureau of Shipping.

Committee C

Capt. C. A. McAllister, *Chairman*, Vice-President, American Bureau of shipping
Capt. R. D. Gatewood, *Vice-Chairman*, U. S. N., United States Shipping Board Emergency Fleet Corporation
Col. E. A. Simmons, President, American Marine Association
John W Gray, Newport News Shipbuilding and Dry Dock Company
Capt. John F. Milliken, Secretary, Neptune Association.

Under Committee A (on organization) three technical supervisory committees will be created as follows:

1 Committee on Hull Details
2 Committee on Engineering Details
3 Committee on Ship Operating Details and Consummable Supplies.

Through each of these technical supervisory committees there will be formed a large number of subject committees to which will be assigned the task of studying and formulating a standard for such specific items as will from time to time be designated by the executive committee. At the April meeting the committee confirmed the appointment of A. V. Bouillon as its secretary.

LIBRARY NOTES AND BOOK REVIEWS

Sampling and Analysis of Coal, Coke and By-Products

Sampling and Analysis of Coal, Coke and By-Products. Methods of the U. S. Steel Corporation. Second edition, 1923. Published by The Carnegie Steel Company, Pittsburgh, Pa. Leather, 5 × 7¾ in. 184 pp., illus., tables, $3.

Reviewed by C. P. Menges,[1] New York, N. Y.

This little book contains a collection of the methods of sampling and analysis of coal and its derivatives to be used as a guide for its evaluation as a fuel or by-product, and compares very well with the best literature on this subject.

The methods chosen are those which have recently been found to be the most accurate and rapid and which can be followed out in most analytical laboratories. Numerous standard methods outlined in this volume were taken from the proceedings of the American Society for Testing Materials and the Bureau of Mines, where both chemical and physical tests on this subject have been carefully investigated. Also a number of special tests by different authors are quoted.

In reviewing that part of the work in which no outside references are made, a similarity of methods is noticed to those found in the best chemical literature and textbooks from which the fundamental methods were taken, with the addition of such tests and apparatus as special investigators on this subject have found to be of additional value in the examination of these various products.

Alternative methods are frequently given, so that there is a choice as regards the kind of apparatus at hand and the time required to make the analysis.

In conclusion it may be said that the book is complete in itself. The preparation of the standard solutions necessary to make the analysis are described in detail, and also the various tables required for the calculations are included, so that the necessity of consulting other books is eliminated.

Automobile Chassis. By Ben G. Elliott. McGraw-Hill Book Co., New York and London, 1923. Cloth, 5 × 8 in., 233 pp., illus., $2.50.

A textbook for students of automotive engineering. Treats all parts of the gasoline automobile, except the body, the power plant, and its immediate accessories. Particular stress is put upon fundamental principles. These are illustrated, as far as possible, by examples from modern practice, so that the work is useful for reference as well as for instruction.

[1] Chemist, New York Edison Company.

Business Cycles and Unemployment. Report and Recommendations of a Committee of the President's Conference on Unemployment. McGraw-Hill Book Co., New York and London, 1923. Cloth, 6 × 9 in., 405 pp., charts, tables, $4.

Report of an investigation of the whole problem of unemployment and of methods of stabilizing industry so that business depressions would be prevented. This volume contains also the report of an investigation made, at the request of the Committee, by the National Bureau of Economic Research. The latter report discusses the relation of business cycles to unemployment, cyclical fluctuations in employment, and proposed remedies for cyclical unemployment.

Consolidated Textile Catalogs, 1923. Compiled by *Textile World*. Bragdon, Lord & Nagle Co., New York, 1923. Cloth, 9 × 12 in., 531 pp., illus.

This catalog is intended to provide firms engaged in the textile industry with a conveniently arranged collection of catalog information, similar to that available for other lines. The book describes a large proportion of the textile machinery built in this country, the material being arranged under such heads as cotton machinery, wool and worsted machinery, knitting machinery, machinery for dyeing, drying and bleaching, power-plant equipment, mill supplies, building construction, etc. An index of firm names and an index of products are provided, together with a catalog of books on textiles.

Cosgrove's Handbook of Woodworking Machinery. Cosgrove Company, Owosso, Mich., 1923. Loose leaf, fabrikoid, 8 × 11 in., $15.

Buyers of woodworking machinery will find in this handbook descriptions of the machines and equipment manufactured in this country, prepared in uniform manner and classified so that the different machines may be easily compared. The descriptions explain the principles of each machine, tell the sizes made and their capacities, state the power and floor space which they require, and give the names of the manufacturers. An index and a directory of manufacturers are included. The book is issued in loose-leaf binding, to permit the insertion of new matter.

Elasticity and Strength of Materials Used in Engineering Construction. Section 2. Theory of Simple Flexure. By C. A. P. Turner. Minneapolis, Minn., 1923. Cloth, 6 × 9 in., 108 pp., diagrams, $5.

The second section of Mr. Turner's work deals with the theory of flexure. The development of the exact theory of flexure will prove interesting to the profession, the author believes, as will also the simplified formulas. These are developed in such form that they can be remembered and used without reference to a handbook. The discussion of the stress analysis of beams shows clearly the relation of shear distortion to shear resistance, a relation frequently not understood.

Electric Cranes and Hauling Machines. By F. E. Chilton. Isaac Pitman & Sons, London and New York, 1923. (Pitman's technical primers.) Cloth, 4 × 6 in., 114 pp., illus., diagrams, $0.85.

The object of this book is to describe a number of the more generally used types of electric cranes and hauling machines, together with a few of the accessory specialties used with them, and to explain their methods of operation. The subject is treated in a simple, descriptive manner, on broad general lines. Only the most modern and commonly used appliances are included.

Electric Motors, vol. 1. Chiefly Concerning Direct Current. By Henry M. Hobart. Third edition. Isaac Pitman & Sons, London and New York, 1923. Cloth, 6 × 9 in., 412 pp., illus., diagrams, tables, $4.50.

An advanced treatise by an experienced designer, in which matters of theoretical and practical interest are discussed. The present edition has been completely revised and rewritten. While this volume is mostly about direct-current motors, the author has made no attempt to separate alternating- and direct-current questions sharply, and has included certain important matters in the second volume.

English and Engineering. By Frank Aydelotte. Second edition. McGraw-Hill Book Co., New York and London, 1923. Cloth, 5 × 7 in., 415 pp., $2.

Dr. Aydelotte sets forth the purpose of his book to be to teach the student to write by stimulating him to think for himself about his own problems, about his work, and its place in the world.

The range of the thirty-eight essays in the book embraces many kinds of men and many kinds of writing—from the works of Macaulay and Ruskin to the writings of living engineers and advertisements of manufacturers.

Financial Incentives for Employees and Executives. By Daniel and Meyer Bloomfield. 2 vols. H. W. Wilson & Co., New York, 1923. (Modern Executive's Library.) Cloth, 5 × 8 in., $4.80.

A handy compilation of articles on wage systems, bonus plans, thrift plans, and other plans for rewarding employees, classified and arranged for convenient reference. Part of the material is reprinted from periodicals and reports, the remainder is original with the authors. The work covers a wide field and gives the practice of many firms.

Hutte, des Ingenieurs Taschenbuch, vol. 1, 24th edition. By Akademischer Verein Hütte, Berlin. Wilhelm Ernst & Sohn, Berlin, 1923. Cloth, 5 × 7 in., 1308 pp., diagrams, tables, $2.

The present volume has been thoroughly revised to bring it abreast of modern practice. The section on the mechanics of rigid bodies has been entirely rewritten; that on the mechanics of fluids has been enlarged. Improvements have been made in the section on heat, especially in the chapter on combustion, and in the section on the strength of materials. The chapters on lubricants and on belts and belt conveyors have been rewritten. The section on machine elements has been rewritten and enlarged. Nearly 250 pages in all have been added to the book. A change has been made in the method of selling the book, so that the individual volumes can now be bought separately.

Industrial Electric Heating. By J. W. Beauchamp. Isaac Pitman & Sons, New York and London, 1923. (Pitman's technical primers.) Cloth, 4 × 6 in., 118 pp., illus., diagrams, tables, $0.85.

The primary object of this book is to bring together, for the benefit of the engineer and student, information on the applications of electric heating, particularly to other purposes than furnace and welding work. The book is intended to suggest possible applications and thus to stimulate further inquiry by manufacturers and others who could use electric heating, by calling attention to the variety of uses which it now has.

Interior Wiring and Systems for Electric Light and Power Service. By Arthur L. Cook. Second edition. John Wiley & Sons, New York, Chapman & Hall, London, 1923. Fabrikoid, 4 × 7 in., 458 pp., illus., diagram, tables. $3.

Intended as a guide to modern practice in electric lighting and power applications, and in the design and installation of the wiring for these purposes. Written particularly for superintendents of electrical installations and for wiremen who may be called upon to extend or change existing installations and who need definite information upon the best method of procedure. It is also intended as a textbook for students in trade schools and as a handbook for architects.

Kalender und Handbuch fur Betriebsleitung und Praktischen Maschinenbau, 1923. By Hugo Güldner. 2 vols. H. A. Ludwig Degener, Leipzig, 1923. Limp cloth, 4 × 6 in., diagrams, tables, $1.

A pocketbook designed to meet the wants of engineers engaged in management and operation, or in the manufacture of machinery, rather than in design. Issued in two parts, the first containing the greater part of the text and discussing the materials of machines, machine parts, prime movers, power transmission and auxiliary machinery. Volume two treats of management and also contains mathematical tables. The work is published in inexpensive form and is revised each year.

Mechanical Testing, Vol. 2; Testing of Prime Movers, Machines, Structures and Engineering Apparatus. By R. G. Batson and J. H. Hyde. E. P. Dutton & Co., New York, 1923. (Directly useful technical series.) Cloth, 6 × 9 in., 446 pp., illus., diagrams, tables, $10.

This book, the concluding volume of this treatise on testing, deals with methods and apparatus for testing prime movers, machines and structures. The text is confined to descriptions of mechanical methods of testing, except in certain important cases where hydraulic, electrical, or optical means are employed to supplement mechanical means. Types of testing apparatus for the standard tests, suited for use both in the laboratory and the factory, are also described. Prominence is given to details of importance in the success of test apparatus.

Moedebeck-Taschenbuch fur Flugtechniker und Luftschiffer. By R. Süring und K. Wegener. Fourth edition. M. Krayn, Berlin, 1923. Boards, 5 × 7 in., 920 pp., illus., diagrams, tables, $3.60.

This volume, intended to serve as a concise account of the present state of aerial navigation, suitable for ready reference. Its seventeen chapters are each prepared by an authority and are liberally illustrated with diagrams and photographs; many have short bibliographies. A collection of tables is appended to the book.

Origin and Development of the Quantum Theory. By Max Planck. Oxford University Press, American Branch, New York, 1922. Paper, 6 × 9 in., 22 pp. $1.20.

This is the Nobel Prize address delivered before the Royal Swedish Academy of Sciences, June 1920. It sketches briefly the history of the origin of this important theory and gives a short account of its development and its influence on present-day physics. A brief bibliography is given.

Professor Coker's Apparatus for Determining the Distribution of Stress in Structural and Machine Members. Made by Adam Hilger, London.

This pamphlet is a trade publication describing the apparatus devised by Prof. E. C. Coker for using polarized light to determine the distribution of stress in parts of machines and structures by observations on models made of transparent materials; a method that makes it possible to measure the stress distribution under any system of loads, in any body that can be represented by a plate model stressed in its own plane. As the measurements obtained on models with this apparatus have been found to represent accurately the stresses in metals, the experimental results can be immediately applied to engineering materials. A bibliography is included.

THE ENGINEERING INDEX

(Registered United States, Great Britain and Canada)

Exigencies of publication make it necessary to put the main body of The Engineering Index (p. 117-EI of the advertising section) into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.

AIR FURNACES

Oil-Burning. Melts with Oil in Air Furnace, D. J. Dobson. Foundry, vol. 51, no. 11, June 1, 1923, pp. 436–437 and 466, 1 fig. Coal-burning furnaces used to melt malleable with slight changes in combustion chamber; figures given showing relative cost of coal and oil firing; oil consumption recorded.

Jet Propulsion. Jet Propulsion for Airplanes, Edgar Buckingham. Nat. Advisory Committee for Aeronautics—Report, no. 159, 1923, 18 pp., 8 figs. Discusses method for propulsion by reaction of internal-combustion jet; only hope of success is said to lie in thrust augmentors.

Low-Powered. The Low-Powered Aeroplane, W. H. Sayers. Aeroplane, vol. 24, nos. 18, 19 and 20, May 2, 9 and 16, 1923, pp. 323–324, 343–344 and 363–366, 2 figs. General consideration in light of present developments. May 9: Speed and power; cleanness; weight; wings and body resistance. May 16: Effect of 1 gal. fuel limit; effect of body; engines for light airplanes.

AUTOMOBILE ENGINES

Triumph-Ricardo. Novel Cylinder Block and Crankcase in New British Light Car, M. W. Bourdon. Automotive Industries, vol. 48, no. 20, May 17, 1923, pp. 1078–1080, 6 figs. 4-cylinder engine designed by Ricardo for Triumph car; masked inlet valve and slipper pistons are features; two-bearing crankshaft, splash lubrication, and integral inlet and exhaust manifolds used; bore, $2^1/_2$ in. and stroke, $4^3/_8$ in.

AUTOMOBILES

Wheels. Making Welded Pressed-Steel Automobile Wheels. Machy. (N. Y.), vol. 29, no. 10, June 1923, pp. 757–761, 8 figs. Methods and equipment employed in making automobile and truck wheels by new process.

BLAST FURNACES

Linings, Disintegration of. Solving Furnace Lining Problems, C. E. Nesbitt and M. L. Bell. Iron Trade Rev., vol. 72, no. 22, May 31, 1923, pp. 1603–1607, 7 figs. Laboratory tests are conducted on firebrick for blast furnaces to determine cause of disintegration and its prevention; hard burning is helpful but not desirable; iron-free clay must be used. (Abstract.) Paper presented at Am. Iron & Steel Inst.

BOILER FURNACES

Design. The Influence of Radiant Heat on Furnace Design, A. G. Christie. Power, vol. 57, no. 22, May 29, 1923, pp. 851–854. By simple analogies author pictures behavior of radiant heat waves and their effect on various substances, leading up to analysis of radiant heat in boiler furnaces; suggests designing furnace with maximum amount of boiler-tube surface exposed to fire in order to take up greater amount radiant heat.

BRAKES

Kunze-Knorr. The Kunze-Knorr Air Brake. Ry. & Locomotive Eng., vol. 36, no. 5, May 1923, pp. 143–147, 10 figs. Describes recent German development based on principle of single-cylinder automatic compressed air brake. See also editorial, pp. 149–150.

CAMS

Internal-Combustion-Engine. Internal-Combustion Engine Cams, B. B. Low. Engineering, vol. 115, no. 2995, May 25, 1923, pp. 641–644, 12 figs. Gives mathematical analysis of cams most generally used in internal-combustion engines and considers definite examples showing relative merits as regards average lift, spring strength, noise, etc., of different types.

CENTRAL STATIONS

Diesel-Powered. The Diesel-Powered Central Station. Power, vol. 57, no. 22, May 29, 1923, pp. 856–858, 6 figs. Cites examples where Diesel engine has shown economies impossible with steam units. There are 1100 oil-engine-powered light plants in United States.

COAL

Carbonization. Coal Carbonization as Applied to Power-Plant Practice, V. Z. Caracristi. Power, vol. 57, no. 22, May 29, 1923, pp. 831–836, 4 figs. Low-temperature system of coal distillation; working temperature of oven 1200 deg.; distillation completed in five minutes; coke obtained suitable for boiler firing, powdered fuel or briquetting into domestic fuel.

COST ACCOUNTING

Overhead. Taking the Guesswork out of Overhead Costs, Dale S. Cole. Indus. Management (N. Y.), vol. 65, no. 6, June 1923, pp. 324–326, 1 fig. Shows simple, inexpensive method which permits of more intelligent estimating by small plant, laying particular stress on items of "contributory overhead."

DIE CASTING

Dies. Die-Casting Dies and Their Design, Charles Pack. Machy. (N. Y.), vol. 29, no. 10, June 1923, pp. 804–806, 7 figs. Describes most important points of design and construction in number of die-casting dies, showing methods that may be employed for die-casting white metals into parts of various designs.

DROP FORGINGS

Coarse-Grained. Coarse-Grained Drop Forgings—Their Detection and Correction, L. S. Cope. Am. Soc. Steel Treating—Trans., vol. 3, no. 8, May 1923, pp. 808–823, 28 figs. Review of factors which chiefly contribute to coarse-grained structure, most important of which are excessively high forging temperatures with insufficient amount of mechanical work; discusses methods of detecting coarse-grained fractures and describes method devised by author which has proven satisfactory; importance of proper furnace design, heating temperatures and reductions in hammering metal into dies.

ELECTRIC FURNACES

Gray Iron. Melts Gray Iron by Electric Furnace, G. K. Elliott. Iron Trade Rev., vol. 72, no. 21, May 24, 1923, pp. 1535–1537. Outlines main features of acid and basic electric furnaces, sketches effects upon principal elements of cast iron in comparison with effects obtained through cupola, and discusses problems of cast iron that have arisen through introduction of electric furnace for treating cast iron. (Abstract.) Paper read before Am. Foundrymen's Assn.

ELECTRIC LOCOMOTIVES

4000-Hp. New Electric Locomotives for the Norfolk & Western R. R., T. C. Wurts. Ry. & Locomotive Eng., vol. 36, no. 5, May 1923, pp. 153–155, 4 figs. Features include cab structure carried by side frames; four pairs of drivers in single truck per cab; single 1000-hp. motor per jack shaft; oil-insulated force-cooled transformer; unique arrangement to reduce torque on any motor to present slipping. See also description in Ry. Elec. Engr., vol. 14, no. 4, May 1923, pp. 137–140, 5 figs.

ELECTRIC WELDING, ARC

Manufacturing Purposes, Use for. Arc Welding as a Manufacturing Asset, J. F. Lincoln. Elec. World, vol. 81, no. 20, May 19, 1923, pp. 1147–1148, 1 fig. Points out that arc welding can be of greatest service in manufacture of parts which are usually made of cast iron, and gives examples; also enumerates the advantageous features of properly arc-welded joint.

EMPLOYEES, TRAINING OF

Plans. How Labor Can Be Made More Productive, Harold C. Smith. Am. Mach., vol. 58, no. 22, May 31, 1923, pp. 793–796. Educational activities of Nat. Metal Trades Assn. Five plans for training workers; purpose of industrial training.

EMPLOYMENT MANAGEMENT

Personnel Practice. Present Tendencies in Personnel Practice, Robert F. Lovett. Indus. Management (N. Y.), vol. 65, no. 6, June 1923, pp. 327–333, 2 figs. Study of personnel procedure in 74 industrial and commercial concerns.

FACTORIES

Building Planning. Buildings from The Manager's Viewpoint, G. L. H. Arnold. Management Eng., vol. 4, nos. 5 and 6, May and June 1923, pp. 329–333 7 figs., and 417–421, 10 figs. May: Foundation, floors, and ceiling for well-planned factory. June: Planning roof; partitions, doors, and equipment.

FLOW OF WATER

Electrical Measurement. Electrical Measurement of Velocities of Flow in Pipes, Ivan E. Houk. Engineering, vol. 115, no. 2995, May 25, 1923, pp. 644–645, 3 figs. Describes typical method of measurement based on principle of sudden change in electrical properties of fluid which occurs when charge of salt is inserted; method consists of observing time required for such charge to pass through measured length of pipe, adding salt at intake end, or some other convenient place. Method was used by Miami Conservancy District.

FURNACES, HEAT-TREATING

Electrically Heated. Heat Treat to Remove Strains, Pat Dwyer. Foundry, vol. 51, no. 11, June, 1 1923, pp. 429–432, 5 figs. Large turbine frames and other castings of similar character are heat-treated in special electrically heated oven in which casting is raised to approximately 700 deg. Fahr.; describes foundries of General Electric Co. at Schenectady, N. Y.

GEARS

Automobile Non-Metallic. Study of Material and Methods Needed in Non-Metallic Gear Production, J. Edward Schipper. Automotive Industries, vol. 48, no. 20, May 17, 1923, pp. 1084–1086, 4 figs. Quiet gear-driven front end obtained; tests with typical product indicate blanks are more expensive than metallic type; fewer tear-downs and easier inspection offset extra cost.

HYDRAULIC TURBINES

Draft Tubes. Results of Tests on Five Types of Draft Tubes. Power, vol. 57, no. 22, May 29, 1923, pp. 859–862, 6 figs. Tests conducted for purpose of securing comparison of performance between older forms of elbow draft tubes, type of recently developed and new symmetrical types of draft tubes.

HYDROELECTRIC PLANTS

Automatic. Automatic Plants Aid Western Water-Power Development, E. R. Stauffacher and Gustaf Clinwald. Elec. World, vol. 81, no. 22, June 2, 1923, pp. 1257–1259, 3 figs. Nine semi-automatic generating plants, with total rating of 14,655 kw. now in operation on Southern California Edison system; operating costs reduced approximately 45 per cent.

INDUSTRIAL MANAGEMENT

Cost Control. Managerial Control Through Costs, J. P. Jordan. Management Eng., vol. 4, nos. 2, 3, 4, 5 and 6, Feb., Mar., Apr., May and June, 1923, pp. 81–86, 169–176, 235–240, 335–340 and 399–404, 10 figs. Feb.: Managerial control with direct personal knowledge, without either direct or indirect personal knowledge, and with indirect personal knowledge. Mar.: Cost control. Apr.: Use of general expense accounts. May: Use of departmental burden accounts. June: Keeping up cost reduction.

Greater Production. How Management Can Be Made More Productive, Acheson Smith. Am. Mach., vol. 58, no. 23, June 7, 1923, pp. 831–834. What "greater production" means and why it is necessary; influence on prosperity of scarcity of labor; specific lines of effort that management should follow.

LOCOMOTIVES

Oil-Burning. Mountain and Mikado Types for the 'Frisco. Ry. Age, vol. 74, no. 24, May 19, 1923, pp. 1207–1208, 2 figs. New oil-buring locomotives based on U. S. R. A. designs modified to suit railroads' standards.

OIL ENGINES

Hot-Bulb. The Penney-Porter Heavy Oil Engine. Engineering, vol. 115, no. 2995, May 25, 1923, pp. 652–653, 6 figs. Describes two-cycle engines of hot-bulb type for land and marine use.

Solid-Injection. A Solid-injection Crude Oil Engine. Engineer, vol. 135, no. 3516, May 18, 1923, pp. 523–524, 3 figs. New horizontal type of crude-oil engine, working on 4-stroke cycle, and made with single and twin cylinders in several sizes; feature of engine is facility with which it can be changed over for working with gas instead of oil as fuel.

OPEN HEARTH FURNACES

Reversing Valves. New Type of Open-Hearth Reversing Valve, John Nelson. Iron Age, vol. 111, no. 22, May 31, 1923, pp. 1560–1561 and 1610, 3 figs. Isley combination air and gas-reversing valve is self-contained and all above ground; permits regulation of gas and air supply; without internal moving parts.

PRODUCER GAS

Metallurgical Use. Making Efficient Producer Gas, Waldemar P. G. Dyrssen. Iron Trade Rev., vol. 72, no. 23, June 7, 1923, pp. 1677–1682, 2 figs. Practice as it concerns production of fuel for metallurgical use; theoretical and actual results are compared; modern types of producers designed to provide gas in constant volume and quality. (Abstract.) Paper presented at Am. Iron & Steel Inst.

STEAM-ELECTRIC PLANTS

Detroit Edison Co. New Marysville Plant, Detroit Edison Co., C. Harold Berry. Power, vol. 57, no. 22, May 29, 1923, pp. 824–830, 8 figs. Contains two turbo-generators, one of 10,000-kw. and other of 30,000-kw. capacity, served by four boilers, each having 28,212 sq. ft. of effective heating surface.

Hell Gate, New York. Operating Methods at Hell Gate. Power Plant Eng., vol. 27, no. 11, June 1, 1923, pp. 555–564, 12 figs. Large boiler units impose certain limitations on operating methods; heat-balance control under one operator; station records and test facilities are unusually complete; coal-handling system serves seceral stations; ash handling by sluices.

STEAM POWER PLANTS

Benson Super-Pressure. The Benson Super-Pressure Plant—Its Scientific Basis, P. W. Swain. Power, vol. 57, no. 22, May 29, 1923, pp. 842–846, 6 figs. Study of scientific principles underlying this and other systems for production and utilization of high-pressure, high-temperature steam; Mollier and temperature-entropy diagrams are used in investigating possibilities of various methods of operation.

STEEL MANUFACTURE

Waste-Heat Utilization. Reducing Waste in Steelmaking, H. T. Morris. Iron Age, vol. 111, no. 22, May 31, 1923, pp. 1600–1602. Utilizing heat waste in steel works is said to offer possibilities for improved efficiency; electrification an important factor in eliminating driving energy losses; standardization a valuable method of fighting waste. (Abstract.) Paper read before Am. Iron & Steel Inst.

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Mechanical Engineering

The Monthly Journal Published by

The American Society of Mechanical Engineers

Publication Office, 207 Church Street, Easton, Pa. Editorial and Advertising Departments at the Headquarters of the Society, 29 West Thirty-ninth Street, New York

Volume 45 — August, 1923 — Number 8

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ADVERTISING

Price 50 Cents a Copy, $4.00 a year: to Members and Affiliates, 40 cents a Copy, $3.00 a Year. Postage to Canada, 75 Cents Additional; to Foreign Countries $1.50 Additional. Changes of address should be sent to the Society Headquarters.

Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879.
Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921.

Robert Sibley

H. G. Acres

Myron A. Lee

Peter Payne Dean

F. L. Kallam

Contributors to This Issue

Robert Sibley was born at Round Mountain, Ala., in March, 1881. He was graduated from the University of California in 1903 with the degree of B.Sc., and during the next four years was professor of mechanical and electrical engineering and head of the School of Engineering at the University of Montana. In 1907 he opened an office in Missoula, Mont., as consulting engineer in hydroelectric investigations in the Northwest. He returned to California in 1911 as associate professor of mechanical engineering at his Alma Mater, becoming professor the following year and remaining in that capacity until 1915. He was given a doctorate degree in electrical engineering by that institution last year.

During the next year Dr. Sibley travelled in Japan, China, the Philippines and various industrial centers in eastern and southern parts of the United States. July, 1916, found him back in California once more, as editor of the *Journal of Electricity*, and in 1920 he was appointed president of the McGraw-Hill Company of California. He resigned these positions early this year to become executive manager of the University of California Alumni Association, but still serves the McGraw-Hill Co. as Pacific Coast Consultant.

Dr. Sibley is a vice-president of the A.S.M.E. and a fellow of the A.I.E.E. He is not averse to boosting California's climate on occasion, but his voice is heard more frequently on the subjects of fuel oil for steam-electric generation, and the hydroelectric developments of the Pacific Coast, on both of which he is an authority.

* * * * *

Charles E. Brooks, whose paper on the Recent Development of the Motor Coach is included in this issue, was born at Constantinople in July, 1886. He received his B.Sc. from McGill University in 1908, and soon afterward entered the employ of the Grand Trunk Pacific Railway. He served this railway in various capacities, finally as superintendent of motive power, having supervision over all work in connection with maintenance of locomotives, cars, and shops. When the Canadian lines were recently merged into the Canadian National Railways, Mr. Brooks was appointed chief of motive power of the new organization. The preparation of the paper in this issue at a time when he was assuming the manifold duties of a new position, as well as transferring his headquarters from Toronto to Montreal, is in itself no small achievement.

* * * * *

H. G. Acres writes on the subject of Modern Hydraulic Turbines of Large Capacity. Mr. Acres was born in Paris, Ontario, in 1880. He was graduated by the Faculty of Applied Science, University of Toronto, with the class of 1903. After a short term in the engine room of Canadian Pacific Railway liners between Montreal and Liverpool, he entered the employ of the Canadian Niagara Power Company.

In the Spring of 1905 Mr. Acres went to Arizona as assistant to the chief engineer of the Arizona Copper Company, working on railroad and mill construction. In the Fall of that year he returned to Canada as hydraulic engineer of the Hydro-Electric Power Commission of Ontario, which position he still holds.

Mr. Acres is a member of the Engineering Institute of Canada, the A.S.C.E., and the A.I.E.E. We cannot resist remarking that for a young man Mr. Acres has covered a good deal of ground.

* * * * *

Myron A. Lee was born in Auburn, N.Y., in March, 1887, and was educated in the public schools there and at Cornell University. After his graduation he took the engineering-apprentice course offered by the Western Electric Company and was then employed by that company as equipment engineer. He returned to Cornell, first teaching machine design and then industrial engineering. He took his M.M.E. degree during this time.

Professor Lee left Cornell to accept a position with the Thomas-More Aircraft Corporation, and was assistant superintendent in their plant during the war. He returned to college teaching after the armistice, and is now assistant professor and head of the Department of Industrial Engineering at Cornell.

* * * * *

Peter Payne Dean, who was responsible for the complete design and carrying out of the valve test conducted by the Public Service Electric Co. at their Essex station, Newark, N. J., was born in Staffordshire, England. He attended the Birmingham Technical School and the City and Guilds of London Institute. He served his apprenticeship with Vickers' Sons & Maxim, and then became assistant engineer with the Sturtevant Engineering Co., of London. In 1909 he came to the United States as sales engineer for the Diehl Manufacturing Co. of Elizabeth, N. J., and during his association with this company he completely developed an electrical dynamometer extensively used in the scientific testing of internal-combustion engines.

In 1914 Mr. Dean became associated with the Cutler-Hammer Manufacturing Co., which took over his patents on valve control. Since then he has devoted his time to the design and manufacture of valve-control systems and remote-control devices for central-station use.

* * * * *

F. L. Kallam, who has been awarded an A.S.M.E. prize for his paper on the Thermal Conductivity of Liquids, received his A.B. from Leland Stanford Jr. University in 1921, and his M.E. in 1922. He has been connected with several iron and fuel companies in California since graduation, and is now engaged in the natural-gas-gasoline industry with the Shell Company of California, as gas engineer.

Making America Independent in the Air

Fundamental research in the problems of flight must be the basis for adequate development of air service, either commercial or military. The National Advisory Committee for Aeronautics is in charge of an extremely valuable research program which will be treated in the leading article in the September issue of MECHANICAL ENGINEERING. Many interesting problems and their successful solutions will be described.

// MECHANICAL ENGINEERING

Volume 45 August, 1923 No. 8

The Electrical and Industrial West

A Commercial and Industrial Empire Looks to the Engineer for Its Upbuilding by the Utilization of Its Vast Waterpower Resources

By ROBERT SIBLEY,[1] BERKELEY, CAL.

THE PURPOSE of this article is to give to the reader a conception of some of the unusual engineering feats that are being accomplished west of the Rocky Mountains and to point out some of the reasons why they have been attempted—and in a word to call to the attention of fellow-engineers the vision of the future that prevails among our engineering brothers in that great section of America lining the Pacific.

Due to the scarcity of coal and the necessity for irrigation combined with proper control of flood water and its economic application, the West stands preëminent in irrigation, in flood control, and in hydroelectric development as regards other sections of the world. Hence the engineer here is largely concerned with the var ous ramifications of water and the utilization of hydroelectric power down through the industries. Nature seems to have foreseen in its bounteous provision for our citizens west of the Rockies the crying need for the service of water. In the eleven states west of the Rockies, constituting but 8 per cent of the population, we find 70 per cent of the great undeveloped water powers of the nation. Already great strides have been made in the utilization of this great natural resource. West of the Rockies the average use of electrical power per capita is twice the per capita consumption of the nation as a whole, while in hydroelectric energy the citizen west of the Rockies uses six times the hydroelectric energy consumed by the average citizen of the nation, and in hydroelectric power still undeveloped he has a per capita possibility of twenty-two times that of the average citizen of the nation, even though the East has its great Niagara, Muscle Shoals, and other large power resources.

The general conception of hydroelectric power as it has been developed to date in the West is depicted graphically in Fig. 1. There are no great Niagaras in this empire west of the Rockies, hence the engineer has found it necessary to create artificial waterfalls. His general method is to go up into the mountain gorges, build a dam to store the water, convey this water through a ditch or tunnel, often ten to fifteen miles around the mountain side, at a gradient less than that prevailing in the main run of the stream, and thus create an artificial waterfall of 1000, 1500, and often even greater than 2000 ft. vertical drop. Through giant pipes these waters are dropped against water wheels often of record proportions, thereby developing electrical power which in turn is transmitted to the farm, to the mine, to the home, and to the various industries in the great cities of the West.

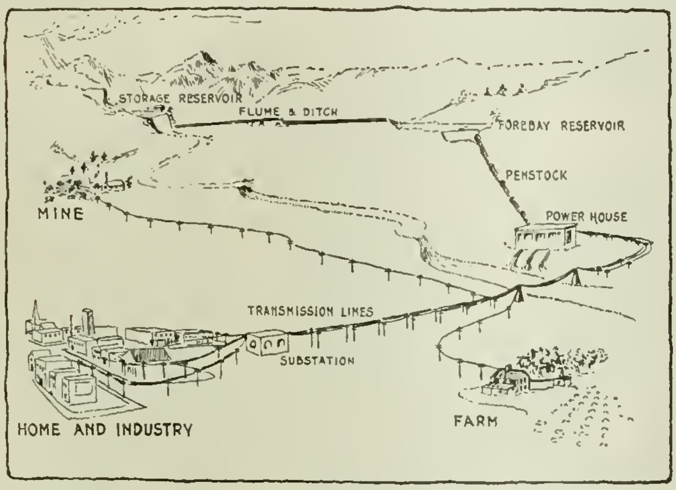


Fig. 1 Sketch Illustrating a Typical Modern Hydroelectric Power System on the Pacific Coast

Let us by pictures follow through some of these record-breaking installations. Fig. 2 is a view of Mt. Shasta in Northern California, the head of a vast drainage area for future power development. Fig. 3 shows some of the many volcanic springs existing to the east of this great drainage area which make possible a constant source of water for power development. The Pacific Gas and Electric Company has undertaken the development of some 600,000 hp. in this region, known as the Pit River development. This company, the largest of its type in the world, ties in with five other great power companies of California, in an interconnected network of approximately a million and a half horsepower, over an area greater than that of New York State, Pennsylvania, and all the New England states combined. Last year the total generated energy of this network was in excess of 4,300,000,000 kw-hr. Assuming the daily work of a human being as the equivalent of one kilowatt-hour, this means that the harnessing of California's mountain streams made possible last year the delivery of energy equivalent to a day's work of four billion, three hundred million people or two and a half times the entire population of the world today.

The view on the cover of the present issue shows the exterior of Pit River Power Plant No. 1. To the left will be seen the power lines which transmit hydroelectric energy at the record-breakage tension of 220,000 volts. This line is 202 miles in length and journeys southward to San Francisco and the industrial centers of central California.

Fig. 4 shows the interior of this power plant constituting the largest 60-cycle generator yet put into commission. The total output of each generator is 46,000 hp.

Fig. 5 is a close-up view of the 220,000-volt transmission line. In the building of this line the copper required for the conductors amounted to 10,000,000 lb., the largest amount ever placed in a single order in an engineering development of this nature.

Many interesting world records have been established in the construction of such great transmission lines as this. One of them is the well-known span at Carquinez Straits near San Francisco, where we find a single span of wire over 4600 ft. in length. Another is the submarine transmission of power from Berkeley, Cal., into San Francisco, through a cable beneath San Francisco Bay, a distance of 7 miles, at 11,000 volts.

In the southern portion of California the Southern California Edison Company is likewise breaking many world records in engineering achievement. The Big Creek Development which is being financed and engineered by this company, has as its goal the ultimate development of 1,400,000 hp. on the various tributaries of the San Joaquin river; particularly, however, on the tributary known as Big Creek. This company has the distinction of having in its interconnected system the successor to the old San Antonio

[1] Pac. Coast Consultant, McGraw-Hill Co., Exec. Mgr., Cal. Alumni Assoc., Stephens Union. Vice-Pres. A.S.M.E.

Abstract of an illustrated address given before the Pacific Coast Regional Meeting of The American Society of Mechanical Engineers, Los Angeles, Cal., April 16 to 19, 1923.

Fig. 2 Mt. Shasta, in Northern California, the Head of a Vast Drainage Area for Future Power Development

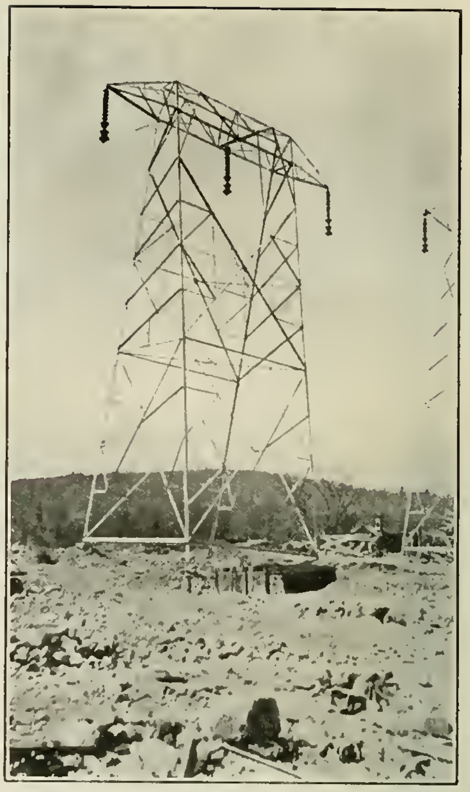


Fig. 5 (At the Right) View of Pit River 220,000-Volt Transmission Line

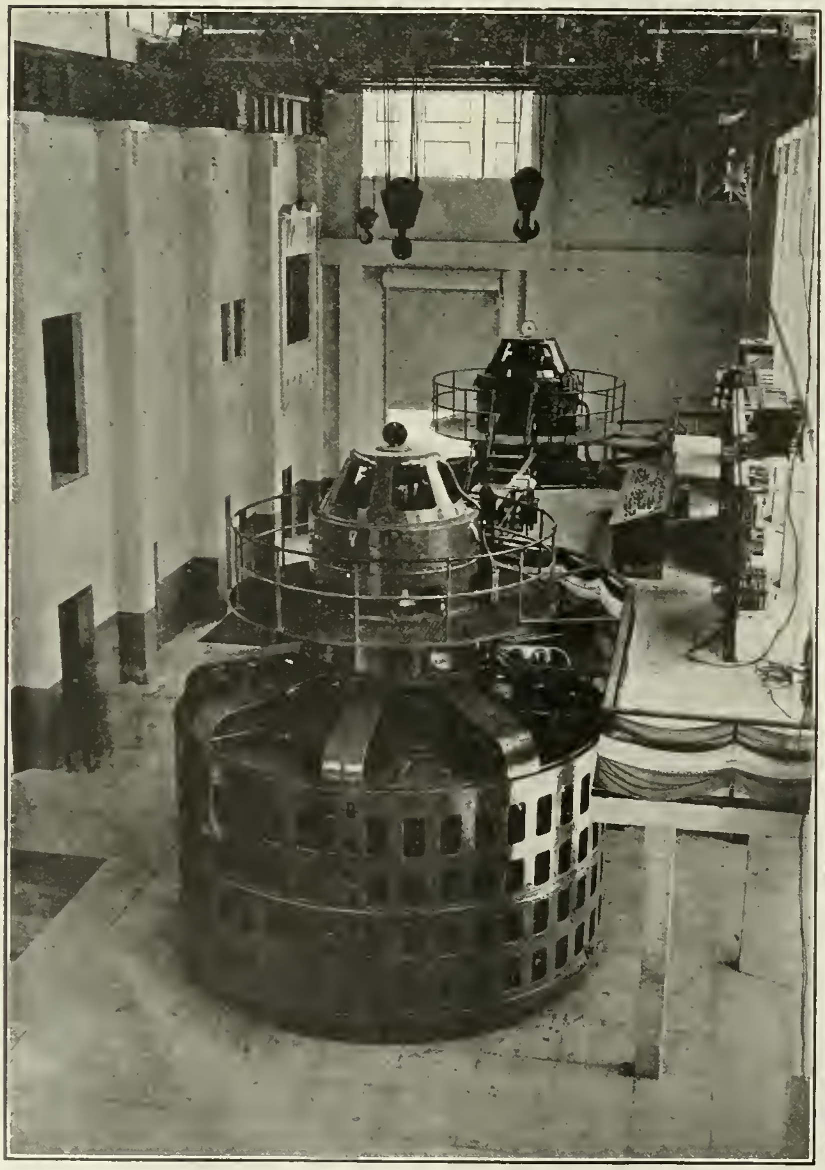


Fig. 4 Interior of Pit River Power Plant No. 1, Showing the Largest 60-Cycle Generators Yet Built. Output, 46,000 Hp. Each

Fig. 3 Volcanic Springs of This Nature Exist to the East of the Mt. Shasta Area and Form a Constant Source of Water for Power Development

Fig. 6 Exterior View of Big Creek Power House No. 1. 64,300 Hp. Installed; Total Head, 2130 Ft.

Fig. 7 Road Construction along San Joaquin River Canyon between Power Houses Nos. 8 and 3 on Big Creek Project

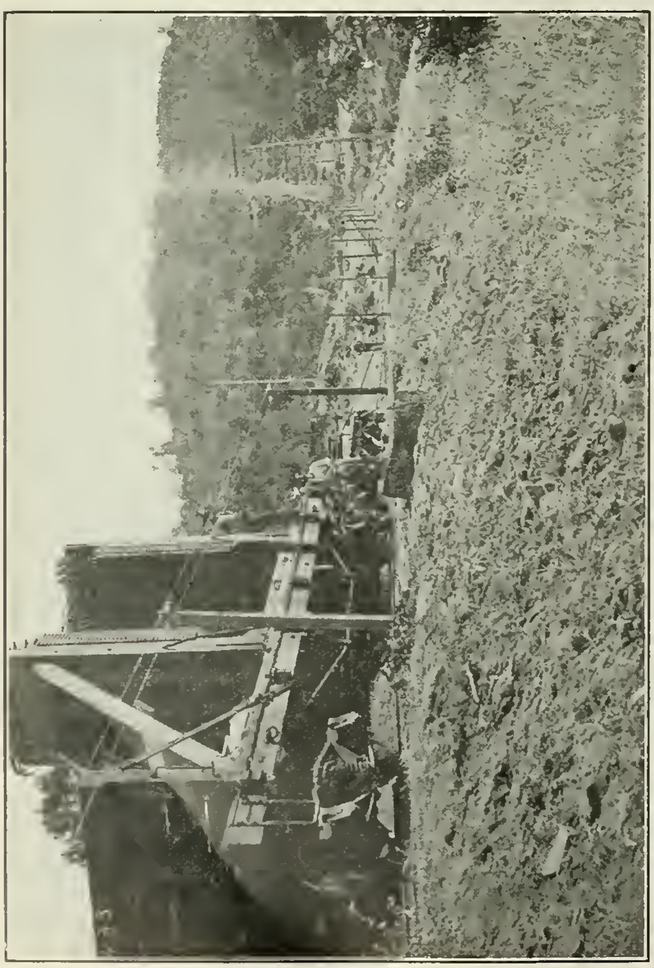


Fig. 8 Half of Stator for 25,000-Kw. Generator at Big Creek Power House No. 3 Being Lowered on Incline to Power House Site

Fig. 9 View of Big Creek Power House No. 8, in Which May be Seen the Surge Chamber and Penstock

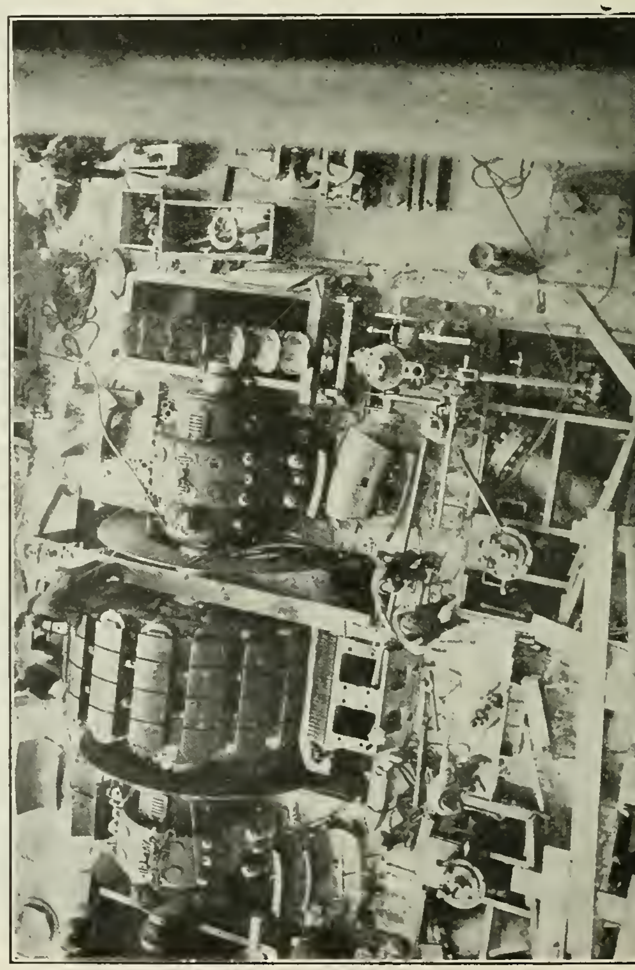


Fig. 10 Looking Down on the Third 16,000-Kw. Unit Being Installed at Big Creek Power House No. 1, Showing Generator in Middle and an Overhung Tangential Water-Wheel at Each End of the Shaft

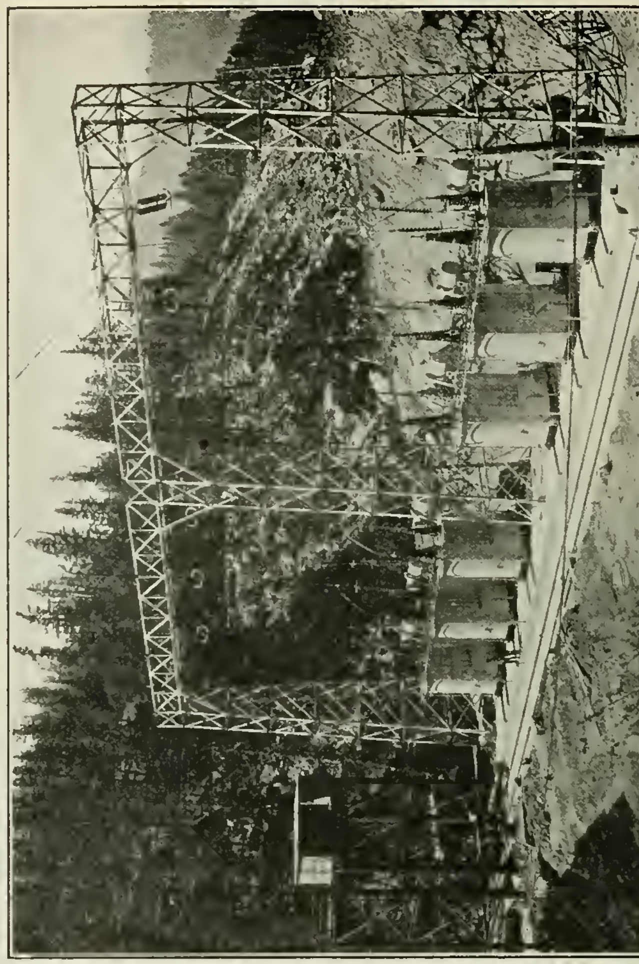


Fig. 11 Two Record-Breaking Banks of Autotransformers at Big Creek Power House No. 1, Used to Step up Voltage from 150,000 to 220,000 Volts. Each Bank is Rated at 52,500 Kva.

power plant, built in 1892, which in its day held the world record for hydroelectric transmission and was the first to transmit power commercially at a higher voltage than that at which it was generated. The length of the transmission line was 20 miles and the voltage of transmission 10,000. Today the giant lines of this same company are transmitting power from this Big Creek Development on the San Joaquin river into Los Angeles, a distance of 240 miles, at a voltage of 220,000.

Records of other California companies are also interesting. It must be remembered that California is a state of such proportions that if the northern boundary could be placed at the Woolworth Building in New York City the southern boundary would be somewhere near Jacksonville, Florida. The Southern Sierras Power Company, flanking the eastern slope of the Sierras in California, which delivers its energy to the deserts to the south in and about the Mexican border line, transmits its power at 87,000 and 55,000 volts over the record distance of 539 miles.

Fig. 13 Beautiful Hetch Hetchy Valley, the Source of San Francisco's Future Water Supply

In the matter of sizes of turbine units, interesting records have been established. The two 30,000-hp., 1008-ft. head units in the Caribou plant of the Great Western Power Company in Northern California comprise the largest high-head impulse turbines thus far put into commission.

Fig. 6 shows an exterior view of Big Creek Power House No. 1, of 64,300 hp. installed capacity, which uses water under a total head of 2130 ft. and is the highest-head hydroelectric plant in America. It will be interesting and instructive to follow in some detail the difficult and unusual processes necessary in the engineering construction and installation of this great record-breaking accomplishment.

Fig. 7 shows the difficult road construction necessary in the San Joaquin River canyon between power houses Nos. 8 and 3 of the Big Creek project. Miles upon miles of such construction are often necessary before installation work proper can be undertaken in western hydroelectric power development.

Fig. 8 shows half of the stator for one of the generators in Big Creek Power House No. 3. This stator is for a generator of 25,000 kw. capacity and is shown in the process of being lowered on an incline down to the power house.

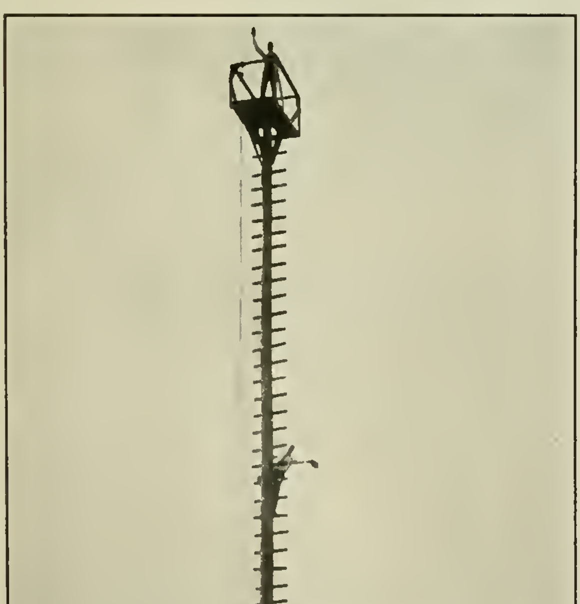


Fig. 12 Temporary Lookout from Which Engineers Take Photographs Daily Showing Progress of Work

Fig. 9 shows the interesting background of Big Creek Power House No. 8, in which may be seen the surge chamber and penstock of this great development.

Fig. 10 gives a view of the third 16,000-kw. hydraulic unit now being installed at Big Creek Power House No. 1. It shows the generator in the middle with the two overhung tangential water wheels plainly in view.

Fig. 11 shows the record-breaking banks of auto transformers at the Big Creek Power House No. 1, used to step up the voltage from 150,000 to 220,000 volts. Each bank is rated at 52,500 kva.

Fig. 12 indicates how the western engineer constructs a temporary lookout near installations of this character, in order that day by day photographs may be taken and a proper history of each day's constructive efforts may be recorded.

Often the mountain scenery encountered in this work is of an exquisite nature. Fig. 13 shows the famous Hetch Hetchy valley, where the city of San Francisco has been expending many millions of dollars in building a great dam near the tree shown in the foreground on the right of the picture. Today this great dam, together with the tunnels and the Moccasin Creek power house of 80,000 hp. capacity in the river 50 miles below, is nearing completion.

After a careful survey of developments now under way, the total program of hydroelectric development in the West as it has progressed from 1910 to date and may be expected to progress to 1930, may be summed up as follows:

	Horsepower Capacity		
Year	Hydroelectric	Steam	Total
1910	800,000	277,300	1,077,300
1911	886,910	324,690	1,211,600
1912	943,010	412,220	1,355,230
1913	1,051,540	467,251	1,518,791
1914	1,175,800	512,870	1,688,670
1915	1,332,430	542,580	1,875,010
1916	1,433,050	545,200	1,978,250
1917	1,566,390	554,680	2,121,070
1918	1,673,350	558,800	2,232,150
1919	1,701,546	619,344	2,320,890
1920	1,826,164	671,586	2,497,750
1921	2,116,500	742,350	2,858,850
1922	2,366,650	823,740	3,190,390
1923	2,728,670	861,330	3,590,000
1924	2,957,900	911,590	3,869,490
1925	3,210,040	943,760	4,153,800
1926	3,352,530	970,570	4,323,100
1927	3,630,280	973,260	4,603,540
1928	3,978,000	978,620	4,956,620
1929	4,177,740	978,620	5,156,360
1930	4,370,770	981,305	5,352,075

To indicate how undisturbed is the forward movement of hydroelectric development in the West, Fig. 14 is shown. By examination of this chart it will be seen that the upper portion of the black line, indicating the total power consumption in the State of California, has been at an even upward trend for many years past in spite of earthquake, pestilence, world war and financial depression. Hence we can predict with a considerable degree of accuracy the future of hydroelectric development in the years immediately ahead.

Two factors control this growth. Fig. 15 shows California's growth in mining, farm products and manufactures, according to figures from the United States census over a period of 40 years past. From this chart it is seen that farm products have long since outstripped mining. On the other hand, few have thought of California as an industrial state. It was as a consequence with much interest and surprise that its citizens heard recently of the

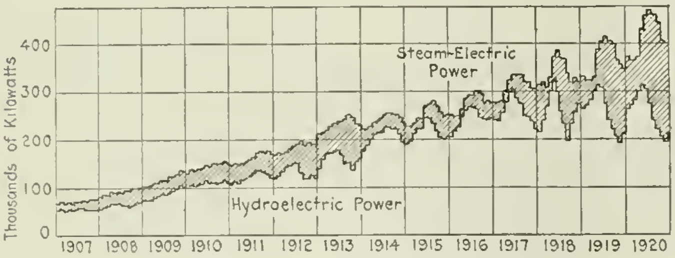


Fig. 14 Chart Showing the Steady Growth in Demand for Electric Power in California Since 1907

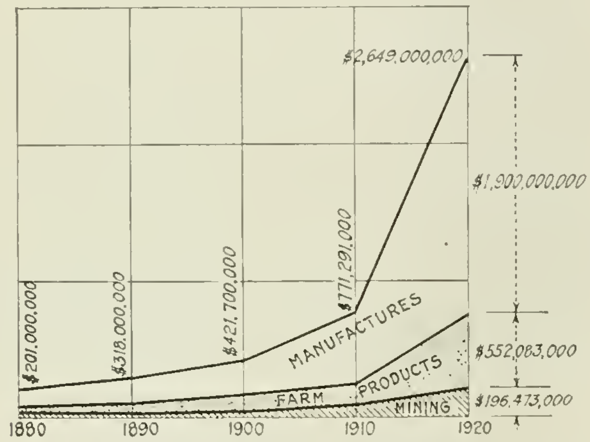


Fig. 15 Chart Showing Growth from 1880 to 1920 of Basic Industries Using Electricity in California

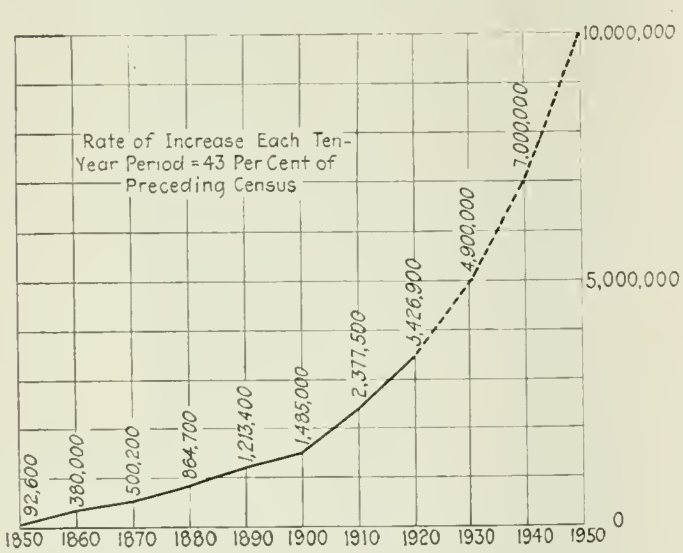


Fig. 16 Chart Showing Increase in Population of California Since 1850, and Predicted Increase for the Next 30 years

announcement by the Census Bureau at Washington that California had taken its place as eighth among the great manufacturing states of the Union, and was the fifth in rank as regarded the number of industrial establishments. In 1920 the value of California's industrial products amounted to one billion, nine hundred million dollars, and today their value is far in excess of this figure.

The other factor that controls California's growth is the matter of population. Fig. 16 shows her increase in population during the past 70 years together with predictions for the next 30 years. According to the census of 1920, California far outstripped any other state in the Union in this regard, her growth in population being 44.1 per cent. There is every reason to believe that, due to the present unexampled growth in the southern portion of the state, California is at present growing at an even more rapid rate; but assuming that her growth continues for the next 27 years as was maintained from 1910 to 1920, California will have a population in the generation immediately ahead of over 10,000,000 people; in other words, she will have a population by 1950 as great as we find today in New York, Pennsylvania, Ohio and Illinois.

A vision of the future takes us to the Pacific Ocean and the countries whose shores it washes, where now live over one-half of all the people of the world. With the vision of daring, enthusiasm, and constructive leadership in the developing of her great natural resources, the West has a destiny of service beyond comprehension, and with her vast waterpower resources she looks to the engineer for the upbuilding of a commercial and industrial empire such as the world has never before witnessed.

Small Electric Plants and Large Systems

The engineering reasons for the advantages of the grouping of many small plants into larger groups are generally known, but may be repeated. There are also similar large advantages to be gained from combining a number of small groups of plants to form a large *system* favorable to economic power supply, financing and management.

To use an illustrative analogy, quoting from the Economic Values of Electric Transmission by F. G. Baum, the large electric system may be compared to a bank in its economic function, and the electric medium of transmission may be compared to money, the medium of property exchange. If we had no money we would have to trade by direct exchange of property, and if we had money but no banks in which to deposit our funds from which those of us who need it might draw, the difficulties of doing business may be imagined. Without a central power-distributing system each consumer must develop his own power and have some surplus power. Hence, there is no medium of exchange, no means of "banking" the total power of all on the transmission system, and no drawing at such points and in such amounts as may be needed from time to time. Electric transmission provides the elastic medium for exchanging any one form of mechanical power to any other form of mechanical power at some point on the system.

Now if one hundred isolated power plants are connected together by a transmission system, and their power-producing possibilities thus concentrated on the system, we will then be able to supply the demands of the one hundred original consumers and have a fair-sized surplus always on hand. That is, by "banking" the individual energies through the medium of the transmission system, we can get all the convenience of the power facilities, and the system will be able to meet the demands of all its patrons—*and carry a surplus.* This is because we have concentrated the surplus of the several plants and because the individual needs do not all come at the same time. This surplus power is principally due to the fact that the diversity of interests now supplied from the one system is such that the system as a whole has a more uniform load, a better "load factor," than the individual plants when operating separately. In general, the more varied the interests which draw power from the lines the more uniform will be the demand, and the better for the transmission system.

Having now connected the hundred small plants by an electric-transmission system with a large power demand, we find we can no longer afford to operate the one hundred small plants, but instead, we install a few large power units to supply the entire system, and by this means produce a large saving in operating expense. The economies resulting from large power systems with large central stations in is in this way working a revolution in America, especially in California, and also in other countries. That this revolution is progressing from economic reasons which are fundamentally sound is certain, and therefore larger and larger electric power systems may be expected. (From Atlas of U. S. A. Electrical Power Industry by Frank G. Baum.)

Recent Developments of the Motor Coach

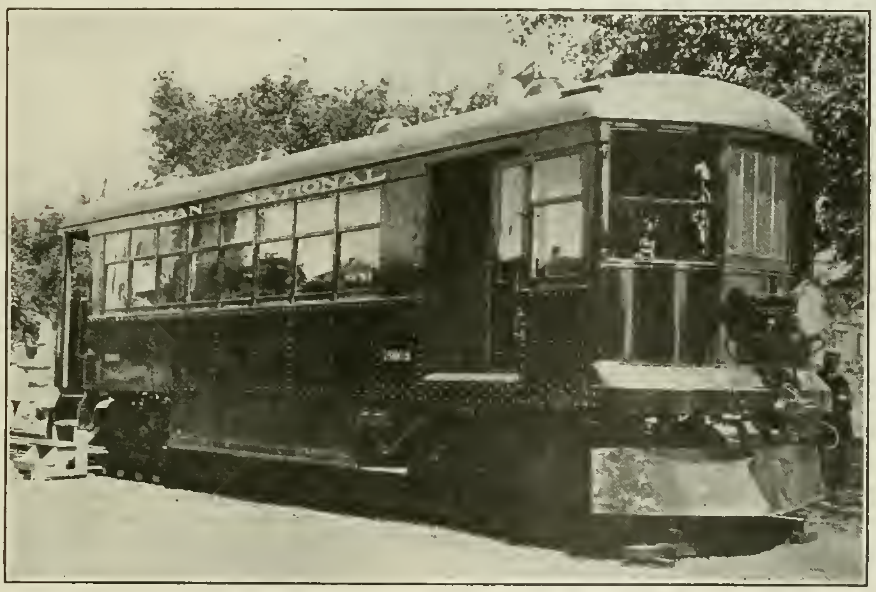
The Renewed Interest Taken in This Type of Equipment and the Reasons Why Railway Officials Have Been Forced to Turn to It—Advantages and Disadvantages of the Various Types of Gasoline-Engine, Storage-Battery, Steam and Gas-Electric Cars—Performance Data

By C. E. Brooks,[1] Toronto, Ont.

THE motor coach is not a new departure in railway work but is instead a branch which on most railways has sunk back from a promising start 15 years ago into obscurity due essentially to high maintenance and operating costs and to the general idea that the motor car was a toy only. During the past three years, however, interest in the subject has been actively revived as a result of

- *a* The ever-increasing encroachment of the motor bus on railway earnings
- *b* The improvement in the design of the motor and its appurtances, and
- *c* The attitude of the public, which the automobile is rapidly convincing that plush seats are not necessary when traveling short distances.

In order to enter into a discussion of present-day developments it will be necessary to outline briefly the service requirements, and in doing so the author must be pardoned if he presents the motor coach as a "unit car" and not as a train of cars or a driving car hauling a trailer. The latter methods of operation may be possible on small interurban or suburban lines, but for practical transportation purposes they are not being considered by many large railways. The reason for this is that up to the present time it has not generally been found to be economical to replace a necessary train service with a motor coach hauling one or more trailers on account of motor-capacity limitations.



Car Fitted with Edison Storage Batteries

On the other hand, high train-mile costs for small returns have forced railway officials to turn to the motor coach for relief in the following classes of service:

- *a* Giving a frequent passenger service on sparsely settled branch lines or parts of main line adjacent to market towns or junction points
- *b* Connecting junction points on important main lines with the town or small city situated within a few miles of the main line
- *c* Giving a group of towns situated on a main line or important branch lines a frequent connecting service over and above through main-line trains
- *d* Connecting small summer resorts, golf clubs, etc., to branch-line or through main-line service
- *e* Handling milk of a limited amount to a distributing or connecting point
- *f* Providing connections to small suburbs.

Among the first real developments of the motor coach was the gas-electric car, the use of which spread rapidly fifteen years ago but which unfortunately did not solve these problems successfully on account of the high maintenance cost of the heavy-duty gasoline motor driving the generator, the very uncertain service, the complications of the equipment, and the great weight of the motor coach itself. Indications are that the gas-electric system with a modern gasoline-engine generating plant is making another bid for this class of work, and a brief description of such a unit is given further on in the paper.

About the same time steam units having very considerable weight and all the complications of the locomotive appeared, but were discarded for much the same reasons as the gas-electric car.

Classification of Present-Day Developments

Present-day developments are generally to provide for traffic requirements, which for the purpose of discussion are subdivided as follows:

Class A—A seating capacity of from 24 to 40 persons and provision for approximately 100 sq. ft. of baggage space. The light weight of such a car to be from 18,000 to 30,000 lb. maximum, or in other words, not to exceed 750 lb. per single seat (with baggage space) or 500 lb. per seat if no baggage space is allowed. In some classes of service the baggage space is given up and seating accommodation substituted.

Smaller cars have been made and are in daily use, but considering the rapid development of traffic after cars are put into service, it is believed that the above-mentioned limits are reasonable.

Class B—Units seating from 40 to 60 passengers and providing for baggage space a minimum of 100 sq. ft. and maximum of 200 sq. ft. As constructed these cars weigh from 800 to 1200 lb. per single seat, but it is thought that the weight must be kept down to the same limits as those prescribed for Class A in order to get fuel economy and keep maintenance costs at a reasonable figure.

Speed Requirements. Schedule speeds of 15 to 25 miles per hour, including stops. Consider a 5-mile run between stops and 1 min. for stops: Acceleration from 0 to 30 m.p.h. in 2 min. on level track, 30 to 35 m.p.h. at end of third minute, an average speed of 35 m.p.h. for the next $3^3/_4$ miles and 0.5 min. to travel 0.21 mile and come to a stop, means that in order to run 5 miles and make one stop the elapsed time is 10.9 min., or an average schedule speed including stops of $27^1/_2$ m.p.h. This allows nothing for loss of time on gradients, slow orders, etc.

Generally speaking, Class A units have been gasoline-driven, and the experience of many railways goes to show that this class of equipment is an economical and lasting development which will be improved to the point of high-grade automobile reliability within a very short time. Already in many places these cars have retrieved business which had been lost to bus lines on the highways and also to the privately owned car, and it has been the usual thing to find that passenger traffic develops to a marked extent after a service has been instituted.

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Presented at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, of The American Society of Mechanical Engineers. Slightly abridged. All papers are subject to revision.

The failures have been rather heavy due to conditions described later in this paper, to the overexacting requirements of time tables, and to non-realization of the limitations of the gasoline motor.

For the purpose of description Class B units may generally be subdivided into (*a*) storage-battery, (*b*) steam, (*c*) heavy-duty gasoline-engine, and (*d*) gas-electric cars.

Class A Cars

The Gasoline-Engine-Driven Motor Coach. For Class A cars weighing approximately 30,000 lb. light weight, the general practice has been to use a high-grade 4-cylinder truck engine running at a maximum speed of approximately 1600 r.p.m. and developing a maximum of 70 hp. Wherever this type of engine has been used it has transmitted its power through clutches, transmissions, and universals to gears, most of which are of standard truck or even heavier design.

Service Car

A general description of a typical power plant such as mentioned above is as follows:

Engine, 4-cylinder, $4^3/_4$ in. by 6 in.
Pressure oiling system
Pump water-cooling system
Primary and secondary transmission
Primary ratio: first speed, 4 to 1; second speed, 1 to 1.
The secondary increases the ratio from 26 m.p.h. for normal engine speed to 35 m.p.h. The first provides for ruling-grade and the second for level-track conditions.

To a much less extent the automobile-type six-cylinder engine of the following general description has been experimented with:

Engine, 6-cylinder, $3^3/_{16}$ in. by 5 in.
Pressure oiling system
Gear ratio, 4.7 to 1 between engine and wheel
Nominal engine speed at 30 m.p.h., 1450 r.p.m.
Horsepower developed, 50 at 2200 r.p.m.
Maximum speed, 2200 r.p.m.
Pump water-cooling system.

In general its power has been transferred through standard automobile clutches, transmissions, etc., which are used with the same type of engine in automobile service.

So far as the actual power plant is concerned, it is the opinion of many that the automobile engine has in almost every way demonstrated its superiority over the truck engine for Class A cars and for general service because of its ability to run over rated speed without serious loss of balance and consequent excessive vibration, and its economy under light load conditions. The first of these reasons undoubtedly embraces conditions which are vital to the successful maintenance of any machine or engine, and it is the author's intention to attempt to explain this from the every-day point of view arrived at through experience rather than from the dynamics of the problem.

Practically any high-grade automobile engine designed for a rated engine speed of approximately 1450 r.p.m. at 30 m.p.h. with a gear ratio between 4 to 1 and 5 to 1 may be driven at engine speeds of 2200 r.p.m. and car speeds of from 50 to 60 m.p.h. without any noticeable vibration of a serious nature. Experience indicates that a similar flexibility cannot be expected from truck engines for any length of time without serious engine trouble developing and possibly resulting in a complete breakdown of the service.

When a motor coach is being operated on a railway where there are schedule connections to make and where there are meeting points designated by train orders and by the time card, it is certain that, regardless of the framing of a schedule, which should not develop an engine speed over that coinciding with the rated speed of 35 m.p.h., the operator will frequently exceed this by 15 or 20 m.p.h. in order to meet the requirements of the service after a delay of any kind. There is nothing parallel to this in highway work with either the automobile or the truck, but it is such an accepted fact on a railway that the only safe course is to provide the type of power plant which will meet these requirements daily without breaking down; in other words, the power plant must be moved out of the sphere of ordinary usage and into what might be called the outer edge of racing conditions. Railway gradients even accentuate this condition, as there is practically no opportunity for letting the engine cool off as there is on the highway.

The automobile engine has been designed not only for easy and economical low-engine-speed conditions, but also for those outlined in the preceding paragraph, and the experience of several railways in this country with a number of cars operating under extremely different conditions seems to bear this out, which leads to the conclusion that the light-weight, high-speed gasoline engine is a satisfactory power plant for the light-weight cars described as Class A.

Class B Cars

The Storage-Battery Car. The general data of a typical unit are as follows:

Car. Interior arrangement, to suit purchaser; weight, 60,000 lb.; length, 53 ft.

Trucks. Two 4-wheel standard M.C.B. axles, except that journals are fitted with roller or ball bearings.

Electric Motors, Etc. Four 25-hp. motors (250–300-volt) mounted with a gear ratio of 16 to 91. Standard series and parallel controller and circuit breaker installed at each end and in baggage compartment; provided with voltmeter, ampere-hour meter, underload circuit breaker and switches for control of air compressor and lighting.

Storage Batteries. 250 cells, capacity 450 amp-hr. at 300 volts, or 135 kw-hr. (580 amp-hr. have been obtained with a minimum of 150 volts).

Battery Charging. Direct current at 250 or 500 volts may be used for charging, and the car is equipped with switches for arranging the battery cells in either series or parallel. Normal rate of charging, 90 amp. Time required for a normal full charge, 5 to 7 hr. A higher rate of charging may be employed provided temperature of battery does not exceed 115 deg. fahr.

Radius of Operation. Maximum 140 miles on a full charge, figuring on level or rolling grade. Recommended not to exceed 100 miles without obtaining a boosting charge.

Power Consumption. Power required, 35 watt-hr. per ton-mile. Acceleration, $^1/_2$ m.p.h. per sec. Maximum speed, 45 m.p.h. on level track. As the car weighs approximately 60,000 lb., 35 watt-hr. per ton-mile is equivalent to 1.05 kw-hr. per car-mile for level track and normal conditions.

Within the above-mentioned radius of operation this car has been extremely satisfactory and is being operated successfully under low-temperature conditions with no appreciable trouble. Its tractive effort of 2400 lb. makes it possible to use a trailer if necessary. The cost of operation, including all maintenance and transportation charges, power, etc., is 17 cents per car-mile. The maintenance has been extremely light, and all indications are that the life of the batteries will be eight to ten years at least.

Steam Cars. The steam power plant was probably the first of any kind to be tried for self-propelled cars, but unfortunately its development has not kept pace with requirements. Medium-pressure (300 to 400 lb.) boiler plants with comparatively low superheat (100 deg. fahr.) were introduced to a considerable extent in continental practice several years ago, but the use of the steam car has not developed, due principally to the excessive weight and general complications of the equipment, and the inefficiency of the boiler plant.

Recent developments indicate that while the seriousness of these defects has been noted and improvements have been made, they have not yet been overcome to the point where steam power may

be considered to be the most satisfactory unit car power, and it may be well to consider these defects more in detail as they appear to exist in modern equipment.

Insufficient boiler capacity is a defect directly coupled with excessive weight of equipment. Boiler plants of approximately 70 boiler hp. nominal rating have been applied to cars with a total net weight in running order of from 50,000 to 60,000 lb. and providing for 100 sq. ft. of baggage space. The total live load will bring this equipment up to a gross weight of approximately 65,000 lb. or a load of 650 lb. per boiler hp.

Experience indicates that for a boiler of this capacity the weight should be reduced by approximately 15,000 lb., and the author has no hesitation in saying that this should be possible as the entire power plant may be carried on the leading (driving) truck and the remainder of the body lightened proportionately. Total absence of vibration should be a very great advantage in lightening the car equipment.

Practically all the first cars of continental make indicated that high pressure and high superheat were necessary in order to provide for a gear ratio sufficient for starting and at the same time for a piston speed of 800 ft. per min. at 40 m.p.h. The engine developed to meet these conditions has no doubt been a great mechanical success, but the boiler plant supplying it has not yet been developed to the point where it can exceed the schedule previously outlined, even under the most favorable conditions. The causes of this deficiency appear to be due to

a Insufficient header volume, resulting in carrying over an emulsion into the superheater units, with a consequent total loss of superheat and excessive water consumption, and

b Unequal distribution of heat to all generating units, resulting in steam pockets and thereby destroying both circulation and evaporative qualities.

The problem of providing sufficient surface-condenser capacity for hot-weather conditions coupled with protective appliances which will be operated by thermostat in cold weather has not been solved, with the result that under maximum conditions the water loss is as high as 45 lb. per car-mile, necessitating replenishing at frequent intervals and a consequent loss of time.

Automatic control of the oil flame has been highly developed but is not yet perfected. Generally speaking, this automatic feature must have two distinct functions: namely, (*a*) cutting off or reducing the fuel supply when maximum boiler pressure is reached, and (*b*) cutting off fuel under low-water conditions. The first-named is undoubtedly perfectly developed but the second is not, due to the varying quality of the steam coincident with the condition (maximum load) which most often causes low water.

The least considered of all conditions in connection with the steam car are probably those affecting the comfort of the operator, and in this respect it is unpopular on account of the extreme heat which may be experienced and also the noise of the oil flame. The latter is by far the most serious, and it is apparently impossible to control it when using high-velocity jets of steam for atomizing.

Space does not permit a further study of the steam plant, but the following general data of a steam car now being tested may be of interest.

Space required for boiler plant, sq. ft.	640
Heating surface of boiler, sq. ft.	385
Heating surface of superheater, sq. ft.	44
Gross weight of car, lb.	60,000
Net weight of complete power plant without oil and water, lb.	13,000
Quantity of water supply, U. S. gal.	200
Quantity of oil supply, U. S. gal.	180
Gallons of oil per car-mile, average	1
Boiler pressure, lb. per sq. in.	800
Superheat, average, deg. fahr.	200
Engine dimensions	6½ in. bore by 8 in. stroke
Gear ratio between crankshaft and axle	1 to 1.46

The Heavy-Duty Gas Car. The general data of a car of this type are as follows:

Car. Length, 55 ft.; weight, 66,000 lb. loaded.

Engine. 6-cylinder, 6¾ in. stroke. Power, 116 hp. at 800 r.p.m. and 225 hp. at 1600 r.p.m.

Transmission. Four speeds forward, three reverse; geared to give 56 m.p.h. forward at 1400 r.p.m. in high and 37 m.p.h. in third speed.

This class of car has not been tested to the point where any accurate data may be given, but it is evident that the gasoline consumption will be at least twice that of a Class A car per car-mile. The problem of handling through transmission and clutch the mechanical drive from a heavy-duty gasoline engine of possibly 200 hp. has not yet been solved unless it may be through the medium of the oil transmission so successfully used in navy work. However, the extreme complication of this transmission or magnetic control makes it doubtful at the present time whether gasoline power plants will successfully exceed 70 hp. in capacity.

The Gas-Electric Car. Mention has already been made of the car of this type which came into prominence about fifteen years ago and which was practically discarded on account of its unreliable power plant and general complication of equipment.

Car Equipped with Six-Cylinder Automobile Engine

The first-mentioned cause of failure has undoubtedly been overcome and reliable constant-speed units are now in general use for generating purposes. If it were possible to eliminate the starting troubles when using types of engines suited for low-grade and cheap fuels, there would be no doubt about the general use of this type of equipment on account of unit power costs. The difficulties mentioned are such an important factor in the successful operation of a motor coach in certain localities that we must necessarily turn to the gasoline engine for generating power.

The gas-electric system provides double-ended control and an efficient starting torque but still retains all the complications of a dual power plant.

The general data of a modern gas-electric car may be stated as follows:

Car. Length, 55 ft.; width, 10 ft.; seating capacity, 54 with 100 sq. ft. of baggage space; weight loaded, 65,000 lb.

Engine. 6-cylinder, governor-controlled, 7 in. bore by 8 in. stroke; develops 150 b.hp. at 900 r.p.m. and drives a 100-kw. 700-volt generator which in turn drives two motors on forward truck. Fuel consumption (estimated), 0.25 gal. per mile.

It is thought that there may be a possibility of employing a smaller-capacity constant-speed gasoline engine (average running power consumption approximating 25 hp. for cars weighing 60,000 lb. loaded) which will drive a generator charging a limited battery capacity. Theoretically this might provide the starting torque desired and at the same time eliminate the undesirable features of the large power plant, but it could not be an economic consideration where cheap power could be purchased.

Ball and Roller Bearings have been one of the most important factors in the development of the motor coach. Exhaustive tests indicate that the ball bearing has reduced starting friction under summer conditions to approximately 15 per cent of that of plain bearings, or in other words has reduced friction of approximately 20 lb. per ton to 3 lb. per ton. At the same time the average rolling friction at speeds up to 30 miles per hour has been reduced by approximately 40 per cent, or from 3.6 lb. per ton to 2.2 lb. per ton.

Experience in this country indicates that the ball bearing is

suitable for Class A cars, but that the areas and sizes for designed industrial work should be at least doubled for railway work due to excessive shocks and side thrusts. It is not possible at the present time to say whether side thrusts are more destructive than vertical rail shocks, but it is certain that for poor rail conditions the bearings should have a side-thrust capacity of 100 per cent of the vertical load.

For Class B equipment it may be necessary to use roller bearings for vertical loads in connection with special bearings for side thrusts.

Transmission and Type of Drive for Gas-Driven Cars

While it has been stated earlier in this paper that the automobile engine is most suitable for the light motor coach, it must nevertheless be admitted that experience indicates that standard automobile transmissions, clutches, universal connections and driving gears are entirely inadequate for motor-coach service and are the cause of probably 75 per cent of the breakdowns. Similar parts which have been developed for truck engines are generally much superior due to their greater size and strength per horsepower transmitted.

The argument has been advanced that the parts are designed for the engine and will handle all the power developed by it; but this contention is not sound, because the greater inertia to be overcome at starting requires a momentary torque much in excess of anything experienced in automobile work.

Account must also be taken of the fact that in this country and the northern part of the United States cars have to be operated in snow storms, resulting in clutch slippage and shocks to transmission which are much in excess of those experienced in automobile service.

The method employed in transmitting the power to the wheels has generally been one of the following:

1 Through a standard transmission to one driving axle which supports the entire two-wheel rear truck and which can move in a vertical plane only. While this is the simplest method of driving, it is not the opinion that it will ever be generally acceptable to the railways as railway experience indicates that safety and good riding qualities are almost proportionate to the number of wheels in the trucks. This is particularly applicable to cars operating on cheaply maintained lines.

2 To both axles of the front four-wheel truck by gearing and universal connections from a transmission located behind the truck. Experience on some railways goes to show that this method is very successful, and although the number of universal connections is not reduced the shafts are all short and the driving forces are entirely removed from the passenger-carrying part of the cars, thereby reducing vibration.

3 To a transmission located at about the center of the car and from there to nearest axle of each four-wheel truck or to both axles of two-wheel trucks. The advantage claimed for this method is that the entire weight of the car is available to give good adhesion (where the trucks are of the two-wheel type), but general experience indicates that this is not necessary and is harder on the engine than an arrangement where part of the momentum of rotating parts may be taken up by slippage. Where four-wheel trucks are used this method has been found to give better adhesive qualities than connecting to both axles of one truck, but the advantage seemingly is not sufficient to warrant the extra complication of transmission.

4 To the leading axle of rear four-wheel truck. The chief advantage of the drive to the rear truck is that the engine may be aligned in such a manner as to have its shaft center line pass through the center line of the main driving axle, thus reducing wear on the universals and friction to a minimum. The disadvantage is that it necessitates the use of one or more supplementary bearings between the engine and the point where the drive shaft is coupled to the front universal. The maximum lateral motion of a truck of 48-in. wheel centers and 18-in. truck centers on an 80-ft. radius curve is shown by road check to average $^3/_4$ in. at a radius from the center of 24 in., so that it is apparent that the swing of the truck has but little effect on the universals. The torque arms supporting the housings of such an arrangement should have both vertical and lateral swing. Only when the load on the main axle is not sufficient for adhesion it may be conceived that driving power acts on the second axle. Under ordinary conditions transmitting power to the second axle generates no more friction than that due to the weight of rotating parts.

Methods of transmitting power from the front axle to the rear axle of rear truck may be subdivided as follows:

a Chain Drive. Chain drive has the disadvantage of rapid wear, noise, and the complication of shields and covers which more than overcome the advantage of the straight drive to the rear truck.

b Gear Drive. Gear drive to the second axle no doubt appears to be the best mechanical means of transmitting power, but it has all the disadvantages of rapid wear due to difficulty of adjustment of contact and the maintenance of extra universals.

c Side Rod and Cranked Wheels. Side-rod drive to the second axle, along with many other locomotive developments said to be crude and inefficient, in actual practice is a thoroughly reliable and easily adjusted and inspected arrangement, and is operating successfully at high and low speeds and with no appreciable friction.

d Miscellaneous, including oil transmissions that are still being experimented with.

Summary

The author realizes that no doubt a very great difference of opinion exists among railway men regarding what type of motor coach will fulfil the requirements of the service best. It is apparent to any engineer that there will be important developments in railway motor cars, both as regards design and field of service, and therefore the following conclusions may be considered as preliminary only.

Class A Cars (30,000 lb. max. light weight), driven by automobile-type, 6-cylinder gasoline engines, should have the following general characteristics and limiting conditions: 1.6 hp. per 1000 lb. light weight of car at engine speed of 2100 r.p.m., giving a car speed of 35 to 40 m.p.h. Rolling friction, 2.2 lb. per ton of weight on rail, and wind resistance of 5 lb. per sq. ft. cross-sectional area of car at 40 m.p.h. Weight of car per passenger seat, maximum 750 lb.; weight of car per maximum hp., 600 lb. Gear ratio between engine and wheel for ruling grades not exceeding 1.25 per cent, 4.7 to 1. (In hard operating conditions this may be increased to 5.5 to 1.)

Class B Cars. It is difficult to come to a general conclusion with regard to this class of equipment, as it appears that only one class of car has actually passed out of the experimental stage. One of the Canadian railways has found the battery car to be a thoroughly reliable and economical unit to operate, provided that the schedule will permit of charging time. Severe weather conditions have had but little effect on the operation, and the simplicity of the power-controlling devices eliminates any chance of opposition from the operators.

The chief obstacles in the development of this type of unit are the first cost and, in some regions, high power costs, but it is felt that the great advantage it possesses of double-ended operation without complication more than offsets any serious disadvantages.

In conclusion, it seems safe to say that there is a fairly large field for the motor coach in railway work and that it will not be developed from without but rather from within—slowly, conservatively, by motor manufacturers and railway engineers, as the traveling public will never tolerate from the railway companies the difficulties and disappointments which have been visited on them personally by the automobile manufacturers. The railway engineer to do his part in this problem must be familiar not only with operating conditions but also with the labor problems which are sure to arise in such a development, making it necessary and advisable to give consideration to the employee operating this equipment and to the public using it.

Discussion

L. Klopman,[1] who opened the discussion, said that he agreed with all that the author had said in favor of the storage-battery

[1] Gen. Mgr., Railway Storage Battery Co., New York, N. Y.

car, but that the paper did not go quite far enough in presenting the proved utility and service of the storage-battery unit.

The author had divided self-propelled cars into two classes placing the storage-battery car in the heavier class (B) but excluding it from the lighter (A), or that for cars having a seating capacity of 24 to 40 passengers, a baggage space of approximately 100 sq. ft., and a car weight of from 18,000 to 30,000 lb. maximum. Storage-battery cars answering this description had been in successful operation since 1917 on the Chattahoochee Valley Railway in Georgia, on the Long Island Railroad in New York since 1914, and elsewhere, which had a seating capacity of 32 to 40 passengers, a baggage space of 80 sq. ft., and a weight, including battery, of 28,000 lb. These cars had been equipped with two 25-hp. 175 to 250-volt motors, double and series-parallel control with a gear ratio of 5.29 to 1, and 150 A-12 Edison cells.

There was no reason why a storage-battery car such as this could not meet every test which had been successfully met by the gasoline-engine-driven motor coaches designated by Mr. Brooks under Class A, and not only meet these conditions, but more economically and with greater reliability in operation than the gasoline car.

It was a matter of common knowledge that the ordinary overhead-trolley car stayed in constant daily service with little or no repair so far as the motors were concerned for periods as long as 20 years.

Assuming the average daily operation of a car in the Class A group to be 100 to 125 miles per day, it was well known that in interurban work the trolley motor performed this service day in and day out, year after year, with only nominal motor repairs and practically no "out of service" conditions.

It was equally well known that no automobile engine would do 100 miles per day continuously, 36,500 miles per year, without considerable repairs and replacement of parts. All automobile owners knew the necessity of frequent regrinding of valves to insure good operation, to say nothing of replacement of piston rings, pitted cylinders, worn gears, transmission shaft, etc., which meant a car frequently out of service for many hours. With such engine equipment the liability existed of complete power failure, and when this happened it necessitated at great expense, annoyance and delay to traffic, substitution by steam service.

The multiplicity of troubles and complete failures which were inevitable with any kind of combustion engine and drive after considerable service necessitating shopping of equipment and consequent substitution, were matters worthy of serious thought. It was generally conceded that the second-hand value of an engine which had run 36,000 miles, or about the equivalent of one year's continuous daily operation, was a very nominal amount, which indicated the large depreciation per annum which must be charged against such a type of car.

This was to be compared with the simple, effective electric motor and control of the storage-battery car, which was as nearly absolutely foolproof as any mechanism yet devised. The four-motor drive permitted in the remote contingency of failure of even two motors, of the remaining two motors' propelling the car. A mechanical or electrical failure of the battery in this service was so remote as to require no consideration. Its initial cost was admittedly higher than that of a gasoline tank, but in a comparatively short period of operation the low cost of maintenance both for the battery and the electric motors soon equalized the difference in initial cost.

The life of the storage battery of which he was speaking had proved to be over ten years in this class of service and, in fact, cars were now in operation in Canada the batteries of which had been installed as far back as 1914. The condition of a gasoline engine started in the same service in that year could be easily imagined.

It was to be remembered that all storage-battery cars were equipped for double-end control, which meant both economy of time and money in operation. The author had cited the use of these cars to connect junction points, small summer resorts, golf clubs, etc. This service would hardly warrant the cost of installation of a Y or turntable such as the one-end operation of a gasoline motor car made necessary, and it would easily be seen that it was only fair that the cost of such installation be deducted from the initial cost of storage-battery operation for both Class A and Class B service.

So far as Class B cars were concerned, he would call attention to the fact that in stating the maximum radius of operation, the author had limited himself to the statement that its maximum radius of operation was 140 miles on a full charge. This statement was correct as far as it went, but in Canada, as well as elsewhere, cars of this size had made and were making up to 235 miles a day where facilities were available and operating schedules permitted the time for intermediate charging. This would give the storage-battery car a mileage which, for all practical purposes, was equal to that afforded by a gasoline-engine-driven car.

R. G. Gage[2] said that one of the chief items that should be watched in connection with storage batteries was the first cost—not perhaps in the car itself, but in the different facilities for making low cost of operation. The charging facilities sometimes were different to procure. The question of operation of the storage-battery car in Canada was important. At certain times of the year, with the temperatures which they had, it was absolutely necessary to start the car out properly charged, but in such cases it had been his company's experience that there was very little trouble. That was one of the serious things that must be given consideration as regarded the proper scheduling, which those having to do with transportation were not always very ready to realize.

J. A. Shaw[3] stated that the railway company with which he was connected had installed four gasoline-engine-propelled cars, which were still in service, to transport passengers from the station to its hotel. They operated for four months each summer and carried all the supplies and fuel as well as passengers. By their installation the use of 200 horses had been done away with and the cost of gasoline for operation per annum was about $1000, which was small.

He had investigated a number of cases where electric cars could be operated. The street-railway company approached was willing to furnish the power required at a very low rate, with practically no charge for auxiliary equipment.

The author, in closing, said that the chief reason why he believed that the gasoline-driven car was the most suitable to fulfil the requirements outlined for Class A cars was the requirements of the service.

These small units were often used in very sparsely settled parts of the country where the only hope railway companies had of making anything out of the service was in its frequency. His company had driven cars fitted with automobile engines on regular schedules which necessitated covering 360 miles per day, up to 50,000 miles before any appreciable repairs had been necessary to the engine.

It was necessary, he said, to differentiate between experience derived from highway-run service and mechanical equipment driven on steel rails. He felt sure, from what he had seen, that the life of a gasoline car motor running on steel rails would be five or more times that of a gasoline automobile motor on highway service.

It was necessary to remember, the author said, that in Canada, where car batteries had to be imported, their cost would run close to $20,000. If necessary, the complete gasoline power plant in one of the Class A cars could be junked every year for practically the interest on that amount alone, without repayment of the cost of the batteries. It might appear at first that it was wise to figure on writing off the value of an automobile engine driving one of these small units after, say 50,000 miles. Experience had indicated, however, that it would be proper to allow 150,000 to 200,000 miles on that kind of service. But even if conditions were such as to make it advisable to junk the engine at the end of 50,000 miles, he still thought it would be better to do this rather than to incur the very heavy expense for the storage battery, which necessitated a large investment in the charging equipment where cheap power could not readily be tapped. He appreciated the value of the storage-battery car, but felt that for certain classes of service it was necessary to have something a little cheaper and a little more flexible.

[2] Signal and Elec. Engr., Canadian National Railways.

[3] Elec. Engr. Canadian Pacific Railways.

Modern Hydraulic Turbines of Large Capacity

A Discussion of the Subject with Special Reference to Refinements in Design, Increased Efficiency, Improved Test Methods, and Advances in the General Art Which Make the Use of Large Turbines Possible

By H. G. Acres,[1] Toronto, Ont.

On New Year's Day of 1905, in the plant of the Canadian Niagara Power Company, it fell to the author's lot to bring up to speed, for the official inspection of the Provincial Park Commissioners at Niagara Falls, Ontario, two 10,000-hp. turbines, the largest units ever built up to that time. Almost exactly seventeen years later it was again his privilege to turn over the first of the five 55,000-hp. turbines now installed in the Queenston plant of the Hydro-Electric Power Commission at Niagara, the largest-capacity units at present in operation. It was this more or less fortuitous combination of circumstances which suggested a subject for discussion.

Not in any sense as a precise definition, but for the purpose of placing a reasonable limit on the scope of discussion, a hydraulic turbine of large capacity may be defined as one having a capacity of not less than 25,000 hp. and a revolving weight, with the generator rotor, of not less than 200 tons, exclusive of hydraulic thrust.

The above limitation on capacity and revolving weight will serve the double purpose of eliminating from the discussion any consideration of low-head installations and at the same time giving prominence to certain problems which become increasingly serious as the operating head ranges upward from 70 or 80 ft. As units of the class which has just been defined above are rarely installed under heads as low as this specified minimum, the discussion is therefore more or less limited to medium- and high-head plants.

Where a high operating head is involved, there is always present the problem of controlling high static pressure in the interests of safety; and in most cases there is also the problem of controlling and utilizing the flow characteristics of long pipe lines to insure not only safe but practicable operation. Finally, where a copious water supply is associated with a high head, there enter the problems of safely and efficiently controlling a heavily energized water column, and handling the immense revolving weight of the modern super-turbine.

Static-Pressure Control

Control of static pressure involved in super-turbine water supply is a vital factor in relation to a maximum degree of safety and convenience in operation, and in continuity of plant output. Obviously the mechanism to exercise this function is a valve, and such a valve, for super-turbine service, must have the following general specifications:

a It must be built in any size necessary to accommodate any conduit, however large.

b It must be designed to operate under any static head, however high.

c Its operation must at all times be safe, sure, and positive, in opening under full static pressure, and in closing under the most serious plant emergencies, such as the breakage of a wheel case or a runaway resulting from failure of governor control.

d It must open and close rapidly, and should have an automatic closing feature to meet the above-mentioned emergency conditions.

Obviously such a specification could not be met by any valve of the ordinary type, nor was it met until the advent of the Johnson automatic plunger valve. This is now an indispensible adjunct to super-turbine installation, and constitutes one of the advances in the general art which contributed to the possibility of present-day super-turbine development.

Flow Control

In the majority of cases the development of a high head involves the use of some type of closed pressure conduit of considerable length. In the case of an automatically governed plant where the ratio of head to length of conduit is more than about 1 : 10, certain phenomena become manifest which constitute a serious menace to safe and practicable operation. The continuous rejection and pulling on of load increments causes recurrent surges throughout the length of the conduit, which, if not damped out or relieved, will sometimes multiply and become superimposed to such an extent as to cause pressures enormously in excess of the static head. This condition, in conjunction with the conversion of pressure into velocity head for acceleration purposes, when a large increment of load is pulled on will impose a duty on the governors which they are not intended to perform, and where long closed conduits are used with turbines gated beyond the point of maximum efficiency, as they nearly always are, a condition may obtain which is entirely beyond the regulating function of the governor.

The power-discharge curve for the ordinary turbine will show a maximum production per second-foot at the point of best efficiency and the first derivative of this curve will show a rapidly decreasing rate of production per second-foot from that point to full gate. Consequently, every horsepower pulled on in excess of best-efficiency capacity will require a rapidly increasing amount of water to produce it. If, therefore, the turbine is operating at or beyond the point of maximum efficiency, when the system demands a large increment of load there will be a falling off in production per unit of water supplied, and coincident therewith a loss of effective head, due to the absorption of such velocity head as is necessary to accelerate the water column. It is therefore evident that during the period when the water column is accelerating, a condition may obtain where the power output is actually falling off while the water input is increasing, the result being that the governor may open the gates full stroke in response to the falling speed, at which point its controlling function will cease, until either the system wr^2 holds the unit, with dropping frequency, for the space necessary for the governor to gradually resume control on rising speed, or until the generator drops its load and the turbine jumps to runaway speed at full gate, with possible disastrous consequences.

In so far as the control of surge pressures is concerned, it is evident that if no practical limitations are placed upon it in the matter of diameter and height, the ordinary standpipe would be an ideal corrective agency. It is clear, however, that in the case of a super-turbine installation unrestricted scope in design is wholly impracticable from the standpoint of both cost and space limitation. On the other hand, a simple standpipe, feasibly designed and located, may at times actually make more acute the conditions it is designed to correct or alleviate. This is due to the fact that the simple standpipe can only passively absorb surge pressure, with its recurrent phases, and for this reason often acts as an agency for superimposing, one upon the other, pressure waves generated by successive changes in load.

Another obvious expedient under this head is to limit the range of velocity change in the conduit by means of a synchronous bypass, actuated by the governor mechanism. This contrivance can be adjusted to prevent the occurrence of disruptive pressures in the conduit, and also to supplement the influence of the system wr^2 in holding the unit within the regulating range of the governor when the unit is pulling on or rejecting load. In this connection it is to be noted that the condition under discussion has not necessarily to do with the maximum conduit velocity at any one time, but with the *range of change* in conduit velocity over a short period of time, and with the absorption and building up of head energy induced by these changes, within their low and high limits.

[1] Chief Hydraulic Engineer, Hydro-Electric Power Commission of Ontario.

Presented at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, of The American Society of Mechanical Engineers. Slightly abridged. All papers are subject to revision.

The synchronous bypass therefore has a useful function, but in the case of a high-head super-turbine installation its usefulness would be largely discounted by its cumbersome dimensions, its waste of water, and an added mechanical complexity which should be avoided whenever possible as a matter of principle.

The discussion under this head has now reached a stage where it is possible to define the specifications of an ideal surge-control agency.

a It should have the effectiveness of a simple standpipe of very large dimensions, without its cost and space requirements.

b It should be capable on the one hand of preventing or counteracting the effect of any undue absorption of head energy when load is pulled on, and, on the other hand, of preventing or counteracting the effect of any serious recurrent surge pressures arising from load rejections, whether isolated or successive.

c The water surface should be sufficiently active to prevent freezing in ordinary low temperatures, and the dimensions should be such as to allow feasible and effective frost protection against extraordinarily low temperatures.

d It should operate without wasting water.

e It should be mechanically simple, with a minimum of moving parts and adjustments.

f It should be entirely dissociated from the governor mechanism, leaving the governor free to perform its own peculiar and highly important function, which is to control the speed of the generator, and not the vagaries of the water column.

This specification has been met with a large degree of effectiveness by one of the most wholly original and at the same time most useful contrivances ever developed in the field of hydraulic engineering, namely, the Johnson differential surge tank. Ample published data are available concerning its structural details and operating principle, and it is only necessary to state here that this contrivance constitutes another of the essential advances in the hydraulic art which have made possible the development and safe operation of the super-turbine.

Revolving Weights

The handling of the revolving weight of a modern super-turbine is governed largely by consideration of efficiency, a matter which will be discussed later, only the mechanical aspect of the problem being considered at this time.

In the early days of hydraulic-turbine development the step bearing, a form of combined thrust and guide bearing located under the runner, was used almost exclusively for the support of revolving element. The subsequent gradual increase in the efficiency, speed, and capacity of turbine runners then began to introduce problems of pressure intensity, depreciation, and accessibility, which the designers of that day solved, not by improving the step-bearing principle, but by abandoning it and inaugurating, as a result, the era of the horizontal-shaft turbine. This led to advanced development in bearings of the pillow-block type, together with the introduction of marine-type thrust bearings to take up unbalanced runner thrust, a double requirement which gave rise to serious problems when the development of electrical generation and transmission called for continuously increasing turbine capacity and speed.

The original turbines installed in 1896 by the Niagara Falls Power Company represent the first reversion to the primitive basic principle. They were the super-turbines of that period, and were of the vertical-shaft type. The revolving weight of these units was partially suspended from and partially superimposed on a step bearing located above the runner and immediately below the generator, thus removing one of the main disadvantages of this type of bearing, that of inaccessibility. A further important innovation was the application of external pressure to a film of oil which was forced in between the moving and stationary elements of the bearing.

The oil-pressure thrust bearing had a vogue of many years' duration, and some bearings of this type are still in operation. Their disabilities are: expensive investment and maintenance cost, mechanical complexity, and high temperature, resulting in low oil viscosity and high energy losses. Also, even a momentary failure of the pressure-oil supply usually results in the loss of the bearing.

Finally there came the ultimate conception, based on the simple and true embodiment of a basic principle first established by the experiments of Tower in 1883 and afterward mathematically demonstrated by Reynolds. It remained for Kingsbury to exemplify this principle in a mechanism which is one of the most outstanding examples extant of the simple and efficient application of a natural law.

The Kingsbury-type thrust bearing has the following characteristics which distinguish it from its oil-pressure prototype and make it an eminently suitable mechanism for supporting, in motion, the revolving weight of the modern super-turbine:

It can be adapted to safely support the revolving weight of the heaviest turbine, within feasible dimensional limits.

The source of oil supply is static, and integral with the bearing itself.

The oil supply is "unlimited" in the sense necessary to conform with the laws of motion of viscous fluids, as enunciated by Reynolds.

The formation of the "pressure wedge" is not induced by any external agency but by the motion of the bearing itself, and by providing for a very slight lack of parallelism between the stationary and moving elements.

The wedge pressure is a direct function of the speed of the moving element, and the thickness of the oil film is a direct function of the degree of viscosity of the fluid, and consequently of fluid temperature, which can be regulated within any desired limits by the simple expedient of water-cooling coils.

Apart altogether from their very material contribution to operating efficiency, the mechanisms above discussed introduce a factor of safety and dependability, either singly or in combination, without which the present-day status of super-turbine development would have been unattainable.

Refinements in Design

The items above classified as essential advances have been radical departures from contemporary practice, and have actually opened up the possibilities of super-turbine development, whereas the turbine governor has been enlarged and improved more or less synchronously with the enlargement and improvement of the hydraulic turbine, and to meet the constantly increasing importance of the duty it has been called upon to perform.

Governors. As the primary requirements of governor operations are precision and reliability, the natural trend of design has been in the direction of simplicity in principle, the reduction of lost motion by the use of minimum of moving parts, and precise shop work. An interesting development along this line is the White shaft governor, where the centrifugal element is attached direct to the main turbine shaft, thus obviating the complication of a belt or gear drive for the flyballs.

The double compensation principle, with the restoring mechanism and load-limiting attachment, appears to meet all requirements of super-turbine governor control adequately and safely, and speed regulation is assured within safe operating limits for all gate movements up to the full stroke of the servomotors.

Remote switchboard control has also been developed to such a stage that there is considerable latitude as to the location of the actuator, which in some cases in now placed directly over the servomotor cylinders, in others on the machine-room floor, and sometimes on the switchboard gallery.

A useful adaptation of the Johnson valve principle has been devised by Taylor for interchanging governor and hand control. Two sets of plunger valves are used, one set on the governor and one on the hand control, and the throwing over of one hand lever will simultaneously close all the governor valves and open all the hand-control valves, or vice versa. This operation can be carried out in such a short interval of time that there is little or no chance of losing control of the turbine, and no chance whatsoever of interfering with the proper sequence of operation.

One of the latest innovations in governor design is a motor-driven centrifugal element, the motor being located on the flyball spindle and synchronously actuated by the main generator. This device serves the same purpose as the shaft governor in that it eliminates the belt or gear drive.

Draft Tubes. The activity which has manifested itself during the last four or five years in draft-tube investigation is directly

traceable to the vogue of the super-turbine. There are two main reasons for this: first, the large concentration of power in a super-turbine permits an appreciable increment of useful power to be reclaimed as the result of a gain of only a fraction of one per cent in overall efficiency; and second, the vibration resulting from vortex action and unsteady vacuum becomes magnified in the super-turbine to such an extent as often to cause serious inconvenience in operation. The pioneer development under this head was the White hydraucone, which marked a distinct advance in this branch of the art.

Briefly, the twofold object of recent draft-tube experimental research has been to regain as much as possible of the whirl component of the velocity head in the runner discharge, and to devise means of so training the combined axial and whirling flow, through appropriately designed water passages, as to minimize conditions giving rise to vibratory effects. All experiments carried on along this line by the principal turbine builders have definitely proved the inadequacy of all forms of the elbow-type tube, and have developed a series of types, more or less correlated, which have given satisfactory results when tested under operating conditions. Of these types the Moody spreading tube seems to conform most nearly to one's conception of the conditions to be met. This is particularly the case in respect of a cone in the center of the Moody tube which extends from the invert to the lower extremity of the runner hub. Inasmuch as this cone solidly fills the region of maximum turbulence, it seems entirely reasonable to assume, even without experimental confirmation, that it will be effective in preventing cavitation and the formation of vortices, with their resultant vibratory effects. Serving this purpose it also naturally follows that it must affect a useful conversion of the hitherto wasted whirl energy of the central zone, realizing thereby a gain in efficiency as well as a betterment in operating conditions.

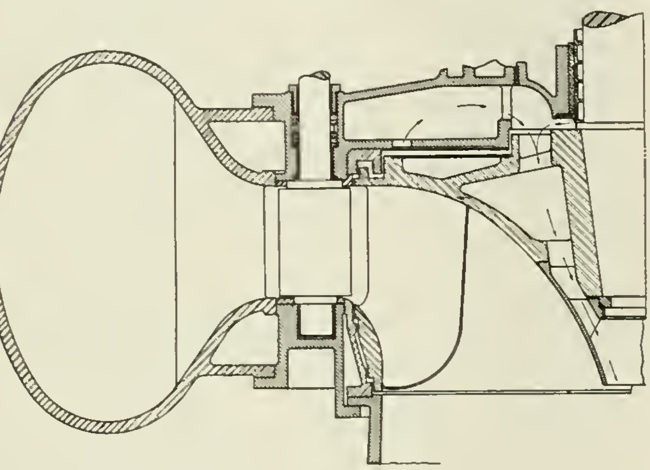

Fig. 1 Showing Application of Labyrinth Seal and Overn Disk to Hydraulic Turbine for Reduction of Leakage

Leakage Prevention. In a small high-head plant with which the author had something to do the turbine showed 85 per cent efficiency on acceptance test. A year later the efficiency had dropped to 67 per cent by reason of excessive leakage through the runner clearance spaces. The head in this case was 550 ft. and the circumference of the clearance spaces was about 14 ft. In the case of the 55,000-hp. turbines at Queenston the head is about 250 ft. less, but the circumference of the runner clearances is about 65 ft. It is evident, therefore, that in the case of a runner of this size, under such a head, the leakage factor is a serious matter. As a matter of fact, two of the most recent refinements in turbine design have been devised for the express purpose of meeting this condition: namely, the so-called "labyrinth seal" for preventing leakage through the runner clearance space, and the Overn disk for preventing leakage through the gate clearances.

Instead of the ordinary simple seal consisting of a straight annular passage past the crown of the runner into the space under the head cover, and a similar passage past the runner band into the draft tube, the labyrinth seal, Fig. 1, consists of a series of alternately expanded and contracted passages which destroy the velocity head and reduce the head on the final free jet to one-third of its initial value.

The Overn disk, Fig. 2, functions by introducing into the clearance space between the end of the gate vanes and the distributor plates an obstruction to the leakage flow considerably greater than the diameter of the gate shanks, thus effectively reducing the leakage at these points.

Taylor Sectional Scroll Case. Where the head is sufficiently high to require the use of a cast-steel scroll case, a serious problem is introduced which has to do with the cantilever strain on the radial joints between the speed ring and the scroll case. With the ordinary design, efficient bolt distribution is not practicable, and in the shop pressure test, where the scroll is not supported by a surrounding mass of concrete, the bolts are sometimes stressed beyond the elastic limit, with resultant serious leakage. This disability can be largely overcome by casting the speed-ring stay vanes integral with the scroll sections, but the pouring and annealing of such a casting is a most difficult piece of work and the results are not always certain. The Taylor sectional scroll case is just as effective and largely removes any uncertainty as to the quality of the casting. Taylor's method, see Fig. 3, is to cast the speed-ring stay vanes integral with a small radial section only of the scroll, and connect later by means of a joint to the main section of the scroll. This joint is so located as to permit of a heavy flange and efficient bolt spacing, and the castings are of such shape and dimensions that there is every assurance as to their quality after leaving the annealing furnace.

The showing made by the sectional scroll case under shop pressure test indicated that no undue risk would be involved in setting the scroll in the open, with only so much concrete as might be necessary to secure a stable anchorage.

With regard to the pitting and erosion of runners, it may be said that super-turbine development has now reached a stage where this condition is no longer primarily a problem of design but of economics. In other words, if the customer so specifies, the manufacturer can select a specific speed and supply, at a price, a turbine in which the runner will have as long a period of useful life as the other major elements of the installation.

Such a specification on the part of the customer would, of course, involve additional capital expenditure for the generator as well as for the turbine, but as against this aspect of the situation it must be realized that the modern super-turbine frequently has a capacity which enables it to earn upward of \$2500 every twenty-four hours. Consequently the lost revenue charge against runner replacement in a fully loaded unit may easily run as high as \$25,000. If this were necessary every two years, it would be equivalent, on a 6 per cent basis, to a capital charge of \$200,000. Such being the case, it is evident that the choice of a proper economic specific speed is a matter deserving the most careful and mature consideration, being a factor of at least equal importance with proper gateage and elevation relative to tailwater.

Fig. 2 Showing Application of Overn Disk to Guide Vanes for Reduction of Leakage

Efficiency

The overall maximum efficiency of the Queenston units is well beyond 90 per cent, and within their maximum efficiency range they deliver about 32 e.hp. to the switchboard for every second-foot of water supplied under 305 ft. of net head. Under such conditions a variation of one per cent, one way or the other, on one of these 55,000-hp. units would mean either the lack, or the availability, of sufficient power to meet the requirements of an average community of 2000 population. This statement should serve to emphasize the significance of high efficiency as related to super-turbine practice.

The primary factor making for high efficiency is a minimum of obstruction to the direct flow of water from forebay to tailrace. This consideration involves water passages of ample section, with changes in direction of flow eliminated wherever possible, and where unavoidable, careful proportioning and transitioning. These requirements constitute the general definition of high efficiency, and are exemplified in the carefully designed annular water passages in the Johnson valve, in the wheel case, speed ring, runner, and draft tube of the modern super-turbine, and also in the total elimination of one change in direction of flow entering the wheel case, by vertically suspending the revolving weight from a Kingsbury-type bearing. Secondary but none the less significant factors are the elimination of leakage, low power loss in thrust and guide bearings, and expert shop work.

The proper handling and correlation of these various factors is exemplified in the results illustrated in Fig. 4, which shows the efficiency and power-discharge curve for one of the Queenston turbines. The matters of interest in connection with these curves are as follows:

1 The maximum efficiency is $93^1/_2$ per cent.

2 The efficiency at the point of maximum discharge is 88 per cent.

3 The turbine has a capacity range of 32,000 to 63,000 hp. at efficiencies of 90 per cent or over, and a capacity range of 37,000 to 60,000 hp. at efficiencies of 92 per cent or over.

Fig. 5 illustrates the overall switchboard efficiency curve of the same unit, and indicates a maximum overall efficiency of 91 per cent.

The outstanding fact in connection with these results is that the modern super-turbine is capable of converting into mechanical energy all but 7 per cent of the gross potentiality of the water supplied. Extreme conservatism in the fixing of specific speed, and the combined effect of further small refinements in the design of water passages, may possibly raise this efficiency another per cent in the future, and may give the curve a slightly more advantageous shape, but it would really appear that the super-turbine of the present day embodies the ultimate in respect of water economy at the point of best efficiency.

Fig. 6 is an interesting curve representing the first derivative of the power-discharge curve of one of the Queenston turbines. As its name implies, this curve is derived by plotting the amounts of horse power per second-foot produced, in various regions of gate opening at and beyond the point of maximum efficiency, by a very small opening movement of the gates. In other words, it shows, not the gain, but the rate of gain in power for increasing water input.

It will be seen that when operating at the point of maximum efficiency with a water input of 1600 sec-ft. the gain in power for one additional second-foot supplied is 32 hp. On the other hand, at full gate, when the turbine is taking water to the extreme limit of gate opening, the gain in power for one additional second-foot supplied is only about 10.5 hp.

The two extremes above cited serve to illustrate the significance of previous statements made under the head of flow control, and also to confirm the truth of the following statement: that under high heads, where the gross potentiality per second-foot of water

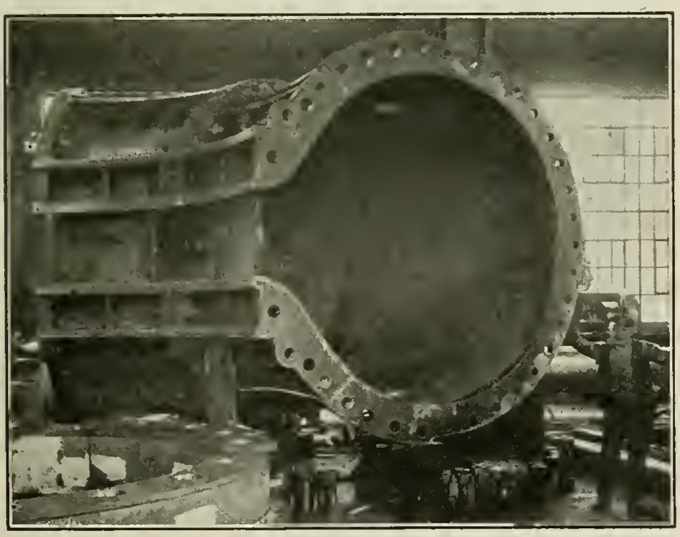

Fig. 3 Section of Taylor Sectional Scroll Case Showing Integral Cast Stay Vanes and Joints Subdividing Sections

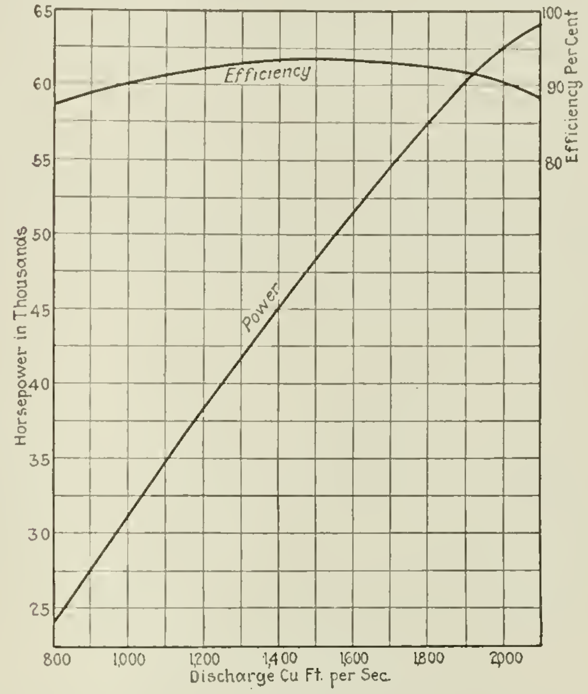

Fig. 4 Power-Discharge and Efficiency Curves of one of the Queenston Turbines

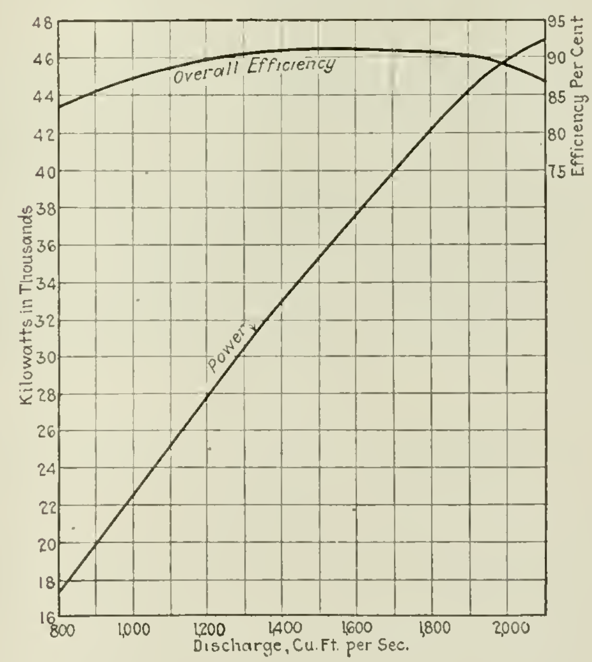

Fig. 5 Overall Efficiency and Power-Discharge Curves of Unit of Fig. 4, Head, 305 ft.

is correspondingly great, it is in the best interests of economy, as well as safety, to operate normally at the point of best efficiency, and to employ the excess capacity of an overgated turbine for emergency purposes only, and not for routine operation. This statement has an added significance, also, when the water supply is artificially stored.

Furthermore it is obvious that as the point of maximum efficiency is also the point of minimum hydraulic loss, the rate of runner deterioration at this point must also be a minimum. From this point on the rate of runner deterioration is an accelerating progression, directly related to the degree of overgate.

The points in favor of gating the super-turbine back to the point of best efficiency are: first, safe and efficient operation, particularly where long pressure conduits are involved; second, economy in the use of water under high heads, where the gross potentiality per second-foot of water is great, and where artificial storage is a factor; and third, on account of runner deterioration, particularly where runner replacement involves a material revenue loss.

The matter of turbine gateage has not, in the past, received the

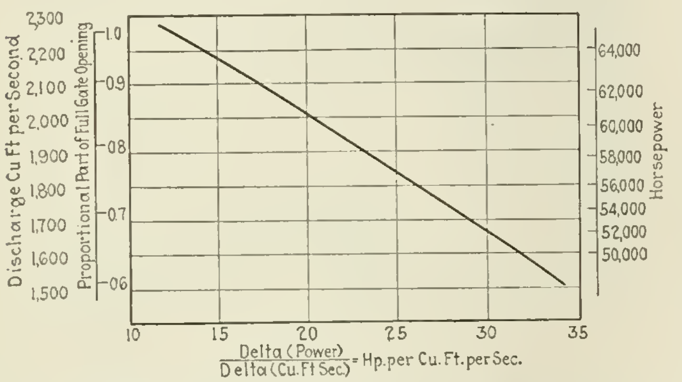

Fig. 6 First Derivative of Power-Discharge Curve of One of the Queenston Turbines, Showing Rate of Gain in Power for Increase in Discharge

attention it deserves at the hands of the purchaser. It does not particularly interest the manufacturer, and must be covered, if at all, by the customer's specifications.

It would also appear that the main factor offsetting the above argument is one of cost and not of engineering: namely, the additional cost, if any, of providing emergency plant capacity in the form of a separately installed unit or units, instead of relying on the overgate capacity of the normal installation.

It may be stated in conclusion that generalizations have probably less weight in hydraulic work than in any other branch of engineering, as nearly every prospective installation is a unique problem in itself, and no class of construction work is less governed by precedent.

Test Methods

The factors entering into a turbine test are forebay and tailwater level measurements, net head measurements, records of gate opening, and measurements of power and flow.

Most of these factors are susceptible of easy and accurate determination by well-established methods, but in the case of flow, the immense quantity of water taken by the modern super-turbine introduces an almost insurmountable problem as regards accurate measurement by ordinary means. It so happens, however, that there has recently been devised a method of flow measurement in closed pressure conduits, which by reason of its accuracy, cheap application, and conformity to an established principle of natural law, entitles it to be classed among the essential advances in the hydraulic art as related to super-turbine practice.

The Gibson Method of Flow Measurement. This method of flow measurement, known as the Gibson process, is based in principle upon Newton's second law of motion, and upon the less generally known theorem of Joukovsky, which is to the effect that when the velocity of flow in a closed pressure conduit is retarded, an oscillatory pressure wave is induced, the intensity and amplitude of which is proportional to the degree of retardation and to the duration of the period over which the retarding influence acts. Briefly, Gibson used the penstock and turbine gates to produce the Joukovsky pressure wave, which he recorded graphically with an apparatus of his own devising, and then reduced the result by the mathematical process of Newton's second law.

The method is therefore almost unique in the field of practical hydraulics in that it involves no empirical constants whatever, and the mathematical accuracy of the result is limited only by a relatively small instrumental and personal error involved in graphically recording and measuring the pressure wave.

The Gibson process has been fully described in the technical press, and it is not the intention here to cover the details of its theory or application. It may not be amiss, however, to describe briefly, the unique and interesting method of obtaining and using the "pressure-time" diagram which forms the basis of computation.

The recording apparatus consists of a mercury U-tube connected to the penstock through a $^1/_4$-in. pipe. The glass leg of this U-tube is connected to a camera box containing a lens focusing on a light-proof cylinder, the latter carrying a sensitized film and revolving at constant speed behind an oscillating seconds pendulum. When gate closure occurs, the mercury column in front of the lens rises and falls with the pressure wave, and the record is printed on the revolving film. At the same time the stem of the seconds pendulum, swinging across the face of the lens, records the time period of gate closure on the film, in the form of a vertical black line.

Fig. 7 illustrates a typical pressure-time diagram thus obtained. The point A represents balanced conditions in the system just previous to gate closure. The distance from A to the vertical line EF represents the full-time period of gate closure. The oscillations to the left of the line EF are due to the mercury column gradually stabilizing by friction, until at the point P static head is registered, with the penstock water column at rest. The vertical distance between the point A and the point P therefore represents, to the scale of the diagram, the recovery of velocity and friction

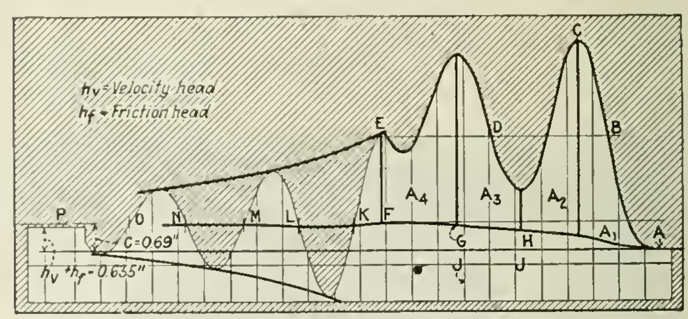

Fig. 7 Typical Pressure-Time Diagram Obtained in Flow Measurement by the Gibson Process

head. The lines J represent the second intervals recorded by the pendulum.

The total area above the base line, and to the point of gate closure at F, represents a total energy absorption containing three separate elements, velocity head, friction head, and the destroyed momentum of the water column. This latter element being the one required for the application of Newton's second law, it follows that the energy absorption due to recovery of velocity and friction head must be segregated.

At the point A it is evident that the full value of velocity and friction head is existent, while it is equally obvious that at F, the point of final gate closure, this energy has been fully recovered. The line $AHGF$, technically known as the "recovery line" divides the total energy area into two parts, the upper part of which, $ABCDEFGH$, represents the value sought, namely, the destroyed momentum of the water column. The area below the recovery line of course represents the sum of the other two elements, friction and velocity head. Intermediate points between A and P on this line are obtainable through the fact that the area generated at the end of any partial period of gate closure is proportional to the amount of flow reduction at that point, and also that the velocity and friction heads still unabsorbed are proportional to the square of the residual flow. The intermediate points C and H

were determined on the basis of these relationships, through the medium of the measured sub-areas A_1, A_2, A_3, and A_4.

A test of one of the Queenston units, with all the other necessary operations in connection with head and gate-opening measurement, etc., was made complete within about four and one-half hours, and included 28 separate runs at various gate openings, an average of ten minutes per run. The unit itself was out of commercial operation for about one hour altogether, showing clearly the facility and cheapness with which the Gibson test can be carried out.

An interesting feature of these tests manifested itself in an apparent inconsistency in some of the finally computed points for the efficiency curve, which varied for equal power outputs. This trouble was due to a discrepancy in the power readings, which were actually correct in themselves within the error limits of laboratory standards. The reason is that under the Gibson process the velocity measured is that existing at the instant the gates begin to move, and if the speed of the unit is perfectly uniform at this instant, the corresponding power reading will be correct for the measured discharge. If, however, at the instant of the flow measurement, the unit is in process of a speed change even so small as to be unnoticed on the frequency meter or tachometer, an error will be introduced in the electrical power measurement which the Gibson process is sufficiently precise to detect.

The flywheel effect of the Queenston generators is 21,000,000 lb-ft.^{2} If, at the instant of a flow determination, the speed of the unit is dropping at even so small a rate as one cycle in ten seconds, there is 570 hp. registered on the wattmeters which the wr^2 of the generator is supplying, but not the water as measured.

Conversely, if the speed of the unit is in process of increase at the rate of one cycle in ten seconds, there is 570 hp. which is not being registered on the wattmeters, but which the water, as measured, is actually supplying, for absorption by the generator wr^2.

This means that for any one value of discharge there may be any number of wattmeter measurements which may possibly be in error in any amount up to 1000 hp. It is possible that this disability may be overcome by devising some simple means of recording the minute speed change of the unit synchronously with the instant of flow measurement, and thus permit a proper correction to be applied to the power readings.

The Salt-Velocity Method of Measuring Flow. The use of the Gibson process is naturally limited to conditions which are properly conducive to the production of the phenomena upon which the theory is based, the first essential being a closed pressure conduit of reasonable length and uniform section. In short conduits of, say, 50 to 60 ft. in length, more especially if they have at the same time a non-uniform section, it becomes necessary to apply correction factors which have a greater relative influence on the ultimate accuracy of the result than is the case with long conduits of uniform section. It so happens, however, that the recently devised Allen "salt-velocity" method of measuring flow is susceptible of application to short as well as long conduits and to non-uniform as well as uniform sections, the accuracy of the final result being dependent, not upon an instantaneous pressure rise, but on the refinement of method and money outlay applied to the injection of a salt solution, the time of passage of which, through a fixed length of conduit, forms the basis of the final computation. Practical applications appear to indicate that it has a useful function and will become a recognized process as related to this branch of hydraulic engineering.

In conclusion, it may be well to call attention to the fact that the definition of a turbine of large capacity, as given in the preamble of this paper, is applicable in particular to the Francis type, as there are now in operation, under heads of less than 70 ft., super-turbines which would come within the definition as regards capacity and revolving weight. These turbines are, however, of the new propeller type and any discussion of this new departure in turbine design would open up a subject far beyond the scope of this paper.

In evidence before the International Joint Commission two years ago the author advocated the propeller-type turbine for the St. Lawrence River Development, and was subjected thereby to severe criticism. However, recent performance, under actual installation conditions, has largely confirmed his views and it is more than likely that the Development, when consummated, as it ultimately must be, will see the propeller-type turbine installed.

Discussion

Written discussions of the paper were submitted by Messrs. R. W. Angus, H. Birchard Taylor, and Lewis F. Moody, extracts from which follow. Professor Angus[1] wrote that much of the paper would apply with equal force to medium- as well as large-sized units, and much of it to low-head as well as to high-head plants. Surges were present in all plants having long closed supply conduits, and their magnitude depended on the friction in the line and on its length and the initial and final velocities in the conduit, as well as on the diameters of the pipe and tank, but was independent of the head on the plant, so that the control of surges was really of more vital importance in low-head than in high-head plants.

The form of draft tube, Professor Angus wrote, was not as important in high-head plants as was generally supposed. In the modern low-head turbine of high specific speed the water entered the top of the draft tube with a high velocity of whirl, and the ordinary bent tube was unable to regain efficiently the energy in the water leaving the turbine. The water in such a tube whirled as it passed around the bend and the discharge conditions were bad. In this case the tube must have a special form, capable of recovering the energy leaving the wheel, and the hydraucone and spreading draft tube appeared well suited to this purpose.

On the higher-head plants wheels of comparatively low specific speed were always used, and it was a relatively easy matter to deliver the water to the top of the draft tube in an axial direction at the load showing highest efficiency, and if this was done the straight tapering tube, or even the quarter-turn, gave very good results. It was true that there would be whirling of the water at all other loads but one, and the spreading tube might show higher efficiencies on these loads than the quarter-turn tube, but as yet there did not seem to be enough evidence available in this connection.

Leakage was a serious matter in high-head plants and, according to the illustration given by the author, was relatively much more objectionable in the high-head, smaller plants than in the larger ones. Water-turbine builders were trying the labyrinth packing which had long been in use on steam turbines and turbine pumps. It was true that in both the latter cases the rings had been used on smaller diameters than on water turbines, and this fact made the use of the labyrinth more problematical in the case of water turbines, although it seemed to offer a good solution of the leakage problem.

In regard to the making of reliable tests, there was serious danger in hurrying the work too much, and it did not seem desirable to shorten the tests unduly. Averages taken over a reasonably long time with steady loads, Professor Angus believed, would obviate the difficulty mentioned by the author, as the latter stated that errors up to nearly 2 per cent were possible.

H. Birchard Taylor[2] wrote that the Queenston project, which had first come to his notice in 1911, had been carried out substantially in accordance with the original program with respect to the unit capacity of the turbines, and that practically every improvement that had been developed in the art of turbine design and construction for high-head turbines had been incorporated in the units there installed.

When units of such large capacities as 60,000 hp. were adopted, the importance of such questions as the attainment and maintenance of high efficiency, the elimination of runner corrosion, the avoidance of dangerous water hammer or vibration, the prevention of permanent injury from wear and tear by the provision of renewable parts, and careful study of operating requirements, became evident. The author had shown the great monetary loss involved in only a few days' shutdown of a unit, and his figures made it clear that an enforced interruption of service would not have to last long to produce a loss exceeding the entire cost of a turbine unit. Any safeguard against such interruption, therefore, would easily justify a large capital outlay.

Still larger units were now being constructed for the Niagara Falls Power Co., namely, of 70,000 hp., and it would appear that

[1] Prof. M. E., Univ. of Toronto, Toronto, Ont., Canada. Mem. A.S.M.E.

[2] Vice-Pres., Wm. Cramp & Sons' Ship & Eng. Bldg. Co., Philadelphia, Pa. Mem. A.S.M.E.

the factors which would put a limit on power capacity in the future would be other than those involved in the construction of the turbine itself; and it was reasonable to believe that units of larger capacity than any yet built, when feeding large systems, would be just as dependable as units of smaller capacity had been in the past when connected to systems of lesser magnitude.

Lewis F. Moody[3] wrote that he believed that any one who read the paper or investigated the manner in which the engineering of the Queenston plant had been carried out would be impressed by the unremitting endeavors of the author and his staff to secure the best possible solution for every element in the plant design, and by their adoption of new solutions for many problems arising whenever a new departure could be demonstrated to have advantages, even if its adoption was entirely contrary to accepted standards. Certain features, such as Mr. Taylor's method of constructing the turbine casing without a separate speed ring, had been worked out for the Queenston plant for the first time. Even in the features which had been previously tried out, however, an additional problem had been introduced at Queenston due merely to the unprecedented size of the turbines.

In his specification for the penstock valve for installations of this magnitude the author enumerated the most vital points which had to be covered. A supplementary feature which should also be considered was that of tightness. If the penstock valve passed any appreciable amount of leakage, it was unfitted for location close to the turbine for the purpose of permitting quick access to the turbine without unwatering the penstock. Another important feature was that the motion of the valve should not require the dragging of an unlubricated surface tangentially over another under a heavy normal pressure caused by the static head. The Johnson valve met both of these additional considerations, as the sealing took place by a motion at a large angle to the sealing surfaces, and only at the time of final closing did a heavy pressure due to the static head force the surfaces against each other, thus effecting extremely tight closure.

In connection with the author's references to the design of spreading draft tube adopted for the last three units at Queenston in which a central core was extended all the way to the runner, Mr. Moody called attention to comparative tests that had recently been carried out for the U. S. War Department at the I. P. Morris laboratory in Philadelphia. The turbine tested was of very much higher specific speed than the units at Queenston and consequently involved a more severe draft-tube problem due to the relatively much greater tangential or whirl component present in the water leaving the runner. A draft tube which successfully met the requirements of this high-specific-speed turbine, however, would be equally applicable to the low-specific-speed turbine, and its ability to regain energy of whirl would be effective in improving over-gate and part-gate performance in a lower-specific-speed installation. The particular form of spreading draft tube showing the highest efficiency in these tests was one in which the central core had been carried to the runner as in the Queenston units. The tests had been undertaken primarily to learn whether it would be possible by a simplification of design or the use of an elbow form of tube to reduce the cost of the power-house substructure sufficiently to balance the loss in efficiency. They had shown that the increase in turbine efficiency secured by using the spreading type of tube was so substantial that its use was fully justified. It might be of interest to mention that this type of tube had been adopted for installation either built or building which aggregated approximately 1,750,000 hp.

With reference to the author's statement that the two 10,000-hp. turbines installed by the Canadian Niagara Power Co. in 1904 were the largest units ever built up to that time, he would say that the first 10,500-hp. turbine at Shawinigan was completed at practically the same time, and that it deserved a special place in this branch of engineering because of its being entirely of American design and because of its many years of successful service.

H. A. S. Howarth,[4] who opened the oral discussion, dealt at some length with the development of the Kingsbury type of thrust bearing and its characteristic features, as well as the influence which the work of Prof. Osborne Reynolds, had exerted on thrust-bearing design. The Michell bearing, which had frequently been described in the English technical press, was of the Kingsbury type and was independently invented by an Australian engineer who acknowledged indebtedness to Professor Reynolds' mathematical treatise.

William White[5] said that he was heartily in accord with what the author had to say in reference to specific speeds. Electrical engineers insisted upon going higher in speeds, which meant a greater liability of pitting. The author was the first representative of the customer that he had heard say that the customer also assumed the liability for some of the changes or damages which necessarily would result in going to these higher speeds.

He appreciated the author's remarks concerning the hydraucone and he wished to pay a tribute to Mr. Moody's work. However, he would call attention to the fact that the hydraucone and the spreading draft tube were one and the same thing, because tests had shown that when the cone was taken out the results were the same. Mr. Moody's work, however, had brought out the fact that the cone steadied the performance of the unit, and its extension up to the hub of the runner might prove a valuable addition.

He appreciated Mr. Moody's reference to the Shawinigan unit, as he had been responsible for its design.

Prof. C. M. Allen,[6] who devised the salt-velocity method of measuring water flow, gave brief particulars regarding it. In this method, which is said to be a very accurate one, a charge of brine is injected under air pressure into the stream flow and its passage between two or more known points is accurately timed. By dividing the volume of the conduit between these points by the time of passage, the rate of flow is obtained. The conductivity of the water varies as its salt content, and the timing of the passage of the charge is effected by means of a stop watch or recording seconds clock and indicating electrical instruments, or by recording electrical instruments.

In his closure the author, replying to Professor Angus, said that it was quite true that surges in low-head installations and draft-tube conditions in low-head installations had not been given much prominence in the paper. The reason was that under low-head conditions these two factors became, in the majority of cases, the major elements of design, and it had been impossible to include an adequate discussion of low-head plants under this particular subhead.

Professor Angus had mentioned the possible interest which might attach to a discussion of the comparative efficiencies obtained on the units at Queenston, using the spreading draft tube as against the elbow type. There was a considerable amount of interesting data available in connection with these comparative tests, but it had not yet reached the stage of coördination and final consideration where it could be profitably discussed.

With regard to the question of error introduced into discharge measurements, it was quite true that in the paper he had given figures that would lead to the inference that error was possible. As a matter of fact, this phenomenon did not occur every time one made a test run for discharge. He had merely mentioned that fact as an interesting feature brought out by a method of discharge measurement that at the present time was sufficiently accurate, and the existence of this error could be more or less counteracted either by multiplying the number of runs for any particular opening or by devising some simple method of keeping track of the minute speed changes of the generator at the time of flow measurement.

Mr. White had spoken of the comparative efficiencies of the hydraucone and the spreading draft tube with the cone, and he thought what he said was quite true in so far as it affected one factor, namely, the overall efficiency. He had been discussing that overall efficiency in so far as it was influenced by draft-tube design, and it was not possibly quite as important as the manifestations which gave bother in the form of vibratory effects. At the time Mr. White made his investigations those vibratory effects had not reached the stage of seriousness which they had at the present time. A decade ago they were simply taken as a matter of course, because they caused no trouble. Under present conditions, due to resonance, etc., they constituted a serious factor in operation.

[3] Cons. Engr., Wm. Cramp & Sons' Ship & Eng. Bldg. Co., Philadelphia, Pa. Mem. A.S.M.E.

[4] Gen. Mgr. and Ch. Engr., Kingsbury Mch. Wks., Philadelphia, Pa. Mem. A.S.M.E.

[5] Mgr. Ch. Engr., Hyd. Dept., Allis-Chalmers Mfg. Co., Milwaukee, Wis. Mem. A.S.M.E.

[6] Prof. Hyd. Engrg., Worcester Polytechnic Institute, Worcester, Mass. Mem. A.S.M.E.

A Practical Laboratory and Drawing-Room Course in Industrial Engineering at Cornell University

By MYRON A. LEE,[1] ITHACA, N. Y.

The paper shows how the early courses in industrial management have been widened in scope to include the engineering phases of the problems of manufacturing. This has been accomplished by supplementing the lecture courses with a practical laboratory and drawing-room course in which the student has his own problem to work out in the design and operation of a modern industrial plant.

A NUMBER of years ago it became evident that the work of the engineer was broadening in scope. The engineer in practice was increasingly concerned with management problems, and it was deemed advisable to give the engineering student some instruction along the line of industrial management. The first attempt at Cornell was by means of a lecture course which proved very popular and was of unquestioned benefit to the student.

The increasing importance of this study to the engineering student was soon evident and the limitations of a lecture course were realized. It is recognized, for instance, in teaching machine design that a lecture or even a recitation course alone cannot accomplish results that can be attained in the drawing room. If a student actually designs some piece of apparatus such as a triplex pump, for example, he acquires and, what is more important, retains a knowledge of machine design which he could obtain in probably no other way. Moreover the knowledge he obtains is not limited in its application to merely the apparatus he has designed, but to a large extent is fundamental and applies to the whole field. This is particularly true if the drawing-room course is correlated with a carefully prepared and well-presented course of lectures which show the application of the principles of the subject to the general field.

It was felt that these well-recognized principles of teaching would apply equally well to industrial engineering, and that a course in which the student applied the principles of industrial management to definite problems would give him a knowledge of the subject which he would retain and could apply to any problem in that field. After several years of experiment and development, a course has been evolved which it is the object of this paper to describe.

Time Study

One part of the work consists in actual time-study practice. This work has no direct connection with the rest of the course and could be given at any time. As a matter of convenience it is usually undertaken during the early part of the second term. Studies are made by the student of actual operations in the university shops. As it has not been found practicable to have the student make a preliminary study, he is given mimeographed sheets which enumerate the elements of each operation to be studied and the time when each reading is to be taken. Before taking the study he is required to demonstrate that he has practically visualized the sequence of the elements making up the operation and will almost automatically know when to take readings. This requirment is the result of sad experience as it has been found that otherwise the student will be confused and will get no dependable readings for the first few runs. It has also been found that it pays to have the student practice reading the watch before he attempts observations on a workman. The standard time-study watch reading hundredths of a minute is used and a person accustomed to seeing an ordinary watch needs some practice before he can quickly read one of these watches, as he must when using the "continuous" method of observation.

Each student is provided with a stop watch mounted on a board of convenient shape and records his observations on the usual type of time-study log sheet. It is possible usually to have not more than ten men taking observations upon one operator. Several complete operations or cycles are observed so that representative times can be obtained.

After the observations are made the student then determines "reasonable minimum" times for each element, and making the customary allowances for personal needs, usual delays, etc., prepares an instruction card for the operation determining standard time for a given number of parts, and also writes a descriptive report of the study.

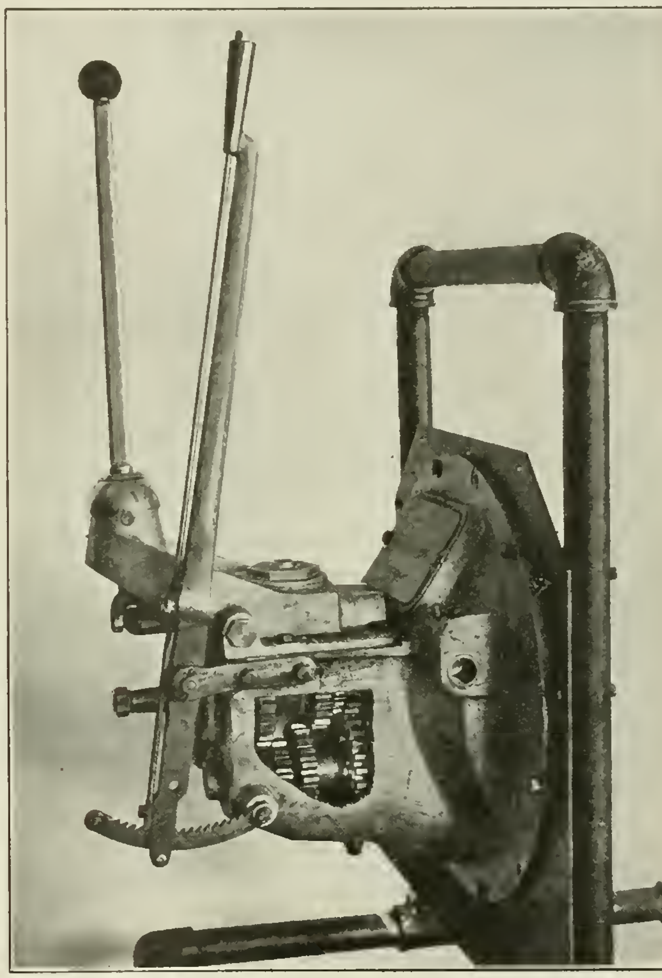

Fig. 1 Automobile Transmission Used as Basis of Student's Mass-Production Problem

Each student makes a time study of operations on perhaps five or six different jobs such as operations on a molding machine, a drop hammer, drills, turret lathes, etc. This work, of course, does not and is not expected to make an experienced time-study man of a student, but it does familiarize him with the taking of a study and stimulates him to a much keener interest in the lectures on the subject which explain the various methods, difficulties, and results of time studies.

A Practical Drawing-Room Course

In the endeavor to develop a satisfactory drawing-room course it soon became evident that specific and definite problems must be used. This was particularly true since the educational problem was one of mass production, a large number of students taking the

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Contributed by the Management Division and presented at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, of The American Society of Mechanical Engineers. All papers are subject to revision.

course. As the problems to be taken up were to apply to factories it seemed advisable for each student to have (on paper) a factory to which his problem could apply. Through the courtesy of the Brown-Lipe Company, of Syracuse, blueprints for one of their transmissions and operation sheets for each part were obtained, and each student makes floor plans of a factory to manufacture a definite number of these transmissions. All students can make use of the same data, but since each is designing a plant

PART NAME *Countershaft Drive Gear* PART NO. *1*
MATERIAL *3½% Nickel Steel*
NUMBER OF PARTS PER TRANSMISSION *1*

OPER. NO.	OPERATION NAME	MACH. NO	MACHINE NAME	NUMBER PIECES PER CYCLE	NUMBER MACHINES RUN BY ONE MAN	CYCLE TIME, MIN.	CHANGE TIME, MIN	SET-UP TIME, HR
	Inspect Forging.							
1	Bore & Face Both Sides	1	J&L	2	1	5.00	–	4 0
	Inspect Bore & Face.							
2	Grind Sides.	2	Grind	1	1	0.50	0 1	2 0
3	Turn O D.	5	Fay	20	2	8.00	1 5	2 0
	Inspect O D							
4	File Corners	48	S.Lathe	1	1	0 25	–	–
5	Block Teeth.	18	B&C Hob	16	2	13.00	5.0	3.0
6	Finish Cut Teeth.	19	Shaper	5	2	11 00	2 5	3 0
	Inspect Teeth							
7	Broach 6 Grooves	3	Broach	4	1	1.00	0 25	3.0
8	C.Sink 6 Grooves	20	S.Drill	1	1	0.40	–	2 5
9	File Burrs		Bench	1	1	0.40	–	–
10	Roll Teeth.	50	Lathe	1	1	0.25	0.3	–
	Final Inspection before Hard							
11	Harden-Carbonize-Brush-							
	Reheat-Quench-Draw & Wash							
12	Sand Blast-Polish for							
	Brinell Test-Test with File.							
13	Grind Bore	22	Heald	1	1	2.4	–	0 5
	Final Inspection.							
14	Repairs							

Fig. 2 Typical Operation Sheet

of different capacity, each man has a different problem. An automobile transmission was used as the basis of this problem as it was not too complicated and was a mechanism with which practically all students are familiar. Experience has demonstrated it to be a wise choice. One of these transmissions (Fig. 1) was mounted in the drawing room so that all students could acquaint themselves with its design and operation. Each student is supplied with sheets detailing the operations on each part. A typical operation sheet is shown in Fig. 2. Also, as an assistance toward a thorough understanding of the problem, manufacturers' catalogs of all machines used were obtained and made available, each machine number as given on an operation sheet referring to a definite machine. For convenient reference each kind of machine used was given such a number, and data of which the following are typical were supplied for each machine.

Machine No. 1

Double-Spindle Hartness Flat Turret Lathe, 3 in. by 36 in.
Mfd. by Jones & Lamson Machine Co., Springfield, Vt.
Floor Space, 4 ft. by 10 ft.
Rated Horsepower, 7.5.
First Cost, $3800.

While the data by which a student determines the number of machines required in his plant are based on one type of transmission, his plant is laid out as it would be for the manufacture of several types. That is, he does not lay out what would be practically a continuous industry.

The first step in the problem is to determine the number of machines of each kind required. This is accomplished by filling out a chart as shown in Fig. 3. From the operation times as given on the operation sheets the number of hours per month required for each machine, for each part, can be computed, and a summary of vertical columns gives the total number of machine hours per month required of each machine. The shop is assumed to run 210 hours per month. If the machines are assumed to operate on the average 80 per cent of this time, then the average number of hours that a machine will operate per month is 168. Dividing the total of a column by 168 gives the number of machines of that type required. As was previously pointed out, each student is assigned a different number of transmissions per month as the capacity of his shop. For this reason the number of machines determined by each student will vary and in this way each will be working on a different problem.

Having determined the number of machines required, the student draws floor plans for a factory to house the machines. Because it makes a more comprehensive problem, a multi-story type of building is required, constructed in conformity to the requirements of the Industrial Code and Labor Law as to exits, stairways, sanitary conveniences, etc. The machines are located for convenient flow of material and also grouped to assist in proper supervision. The chart shown in Fig. 3 is at this time of considerable value as it shows at a glance where and for what purpose a machine is used.

Organization and Production Control

Having the floor plans and data regarding machines, it is possible for the student to attack a large variety of problems. The first one attempted is to make an organization chart for the management of the shop. The theory of organization has been previously discussed in lectures, and the development of functional (or line and staff) organization, as industries grew too large for line organization, has been explained. In the discussion of organization and organization charts the charts shown in Principles of Industrial Organization, by D. S. Kimball, and charts like those by L. V. Estes which have appeared in *Industrial Management* are very helpful. The student is examined on his knowledge of the duties and functions of each department shown in his chart to make sure he has studied the subject and expended thought upon his work. It is considered far more essential that a student expend thought on his solution of this problem than that he arrive at an ideal solution.

Mechanisms of control and the use of orders and returns are next studied. It is assumed that a customer's order is received calling for some parts which can be shipped from stock and some which have to be manufactured. This originates shipping orders

PART NO.	PART NAME	NO. PER TRANSMISSION	MACHINE	1 DOUBLE SPINDLE HARTNESS FLAT TURRET LATHE 3"x36" J.&L MACHINE CO.	2 14" SURFACE GRINDER PRATT & WHITNEY	3 NO 3 B LAPOINTE BROACH J M LAPOINTE CO.	4 SINGLE SPINDLE HARTNESS FLAT TURRET LATHE 2¼"x24"	5 14" FAY AUTOMATIC LATHE J & L MACHINE CO.	6 NO. 6 SEMI-AUTOMATIC LATHE POTTER & JOHNSON	7 NO. 14 NATCO MULTIPLE DRILL NAT. AUTO. TOOL CO.	8 NO 53 ACME AUTOMATIC LATHE NAT. ACME CO.	14" SINGLE
1	Countershaft Drive Gear.	1	2425	210	52.5	31 25		42 4				
2	Large Sliding Gear.	1	2425			75.72			477			
3	Idler Gear.	1	2425	299		75 72						
4	Small Sliding Gear.	1	2425			75 72			598	145 4	-	
5	Interlock	1	4850								24.13	
6	Cover	1	2425									
7	Screws for Cover, Rear Bearing Cap & Brake Lever Bracket	10	97000								2278	
8	Cover Cap.	1	4850				115.2					
9	Rear Bearing Cap	1	2425	230 5	285							
10	Front Bearing Cap.	1	2425	149 5	365							
51	Pin for Part No 43.	1	9700								13.13	
52	Collar for No 43.	1	4850									
65	Lock Wire for No 64.	2	9700									
69	Brake Pawl Rod-Upper.	1	4850									
	Total Hours for 4850 Transmissions per Month			464 9	167 8	551.9	780	2432	1075	145.4	530 5	23
	Number of Machines for 4850 Transmissions per Month			3	2	4	1	15	7	2	4	2

Fig. 3 Chart Used in Determining the Number of Machines Required of Each Kind

production orders, work orders, material issues, etc. It has been found that the use of charts similar to that of Fig. 4 helps to fix the relation of these various forms in the student's mind.

It is pointed out that a separate work order is issued for each operation on each part or lot of similar parts. The method of handling the issuing of stores and keeping of a balance of stores ledger is explained and the forms usually met with are discussed in detail. The student then devises sample forms such as the following: A requisition, material issue, work order, shipping order, production order, and job time card. He must also be able to trace the path of each one of these forms in its travel through the shop, telling who fills in each item and his authority or reason for doing so; also what information is obtained from each form, by whom, and what uses he makes of it. It has been found that this problem gives the student a very real knowledge of the method of using orders and returns for the control of production; he also

gains a knowledge of good practice in the make up of forms and an opportunity is presented for interesting him in the subject of modern job-time recorders, cost-keeping methods, etc.

Cost Analysis

After several lecturers on the subject of cost finding and demonstration of the fact that accurate costs depend on accurate distribution of expense, the various methods in use for this distribution are explained and the student computes an hourly expense charge by the machine-rate method for each machine in his plant. To determine these rates, the student compiles a chart such as that shown in Fig. 5. Such items as cost of pulleys, shafting, motors, tools, jigs and fixtures, furniture, miscellaneous equipment and supplies, and indirect labor have to be assumed and are given to each student on the basis of the number of transmissions he is to manufacture each month. This problem also presents the opportunity for the student to familiarize himself with the operation of a modern duplex adding machine which he uses for totaling columns, etc., in this problem. During this problem the student also gains a speaking acquaintance with the subject of depreciation, as items of depreciation enter into his computations and he attends a number of lectures dealing with the various phases of this subject. The advantages of a good cost-keeping system are explained, as well as the advantages and also disadvantages of the machine-rate method for distribution of expense.

After studying the subjects of routing, scheduling, and dispatching the student is in a position to appreciate the advantages of the Gantt chart which has been so ably explained by Wallace Clark in his recently published book. Using the standard Gantt chart forms each student makes out man-record charts for several operators assumed to be employed in his plant and covering a period of one month for each. He makes all his own assumptions as to the amount of scheduled work each man does, failure to achieve schedule, etc. Next he makes a machine-record chart for the machines operated by the workmen he has listed in his man-record chart, and the two charts must correctly correspond. Finally he makes a layout chart for these same machines and this chart must correspond in each detail with the other two charts. When a student has demonstrated that he can make out these three charts all correctly correlated, it is fairly certain that he has gained a working knowledge of the use of the Gantt chart.

These are the problems now used in this course. It can be readily seen that many others could be devised. The outstanding advantages of the course are that the student has definite, specific problems to attack which are absolutely general in their application. The knowledge he gains makes a lasting impression, and from the standpoint of instruction his work can be easily and accurately supervised, for while each student's problem differs from that of his neighbor, still they are all based on the same data and the same rules will apply to all.

It might be well to mention the fact that this is a course given to men who are students of mechanical engineering ~~and receive~~ the M.E. degree. All students who are to receive this degree have a common curriculum until the end of the junior year, which includes courses in elementary economics and English. During their junior year they all attend a course of lectures on industrial organization which is elementary in scope. In the senior year those who wish to specialize in industrial engineering take the course outlined in this article together with the lectures which it accompanies and a lecture course in safety and fire protection, and may elect courses in accounting, business law, industrial relations, and related subjects.

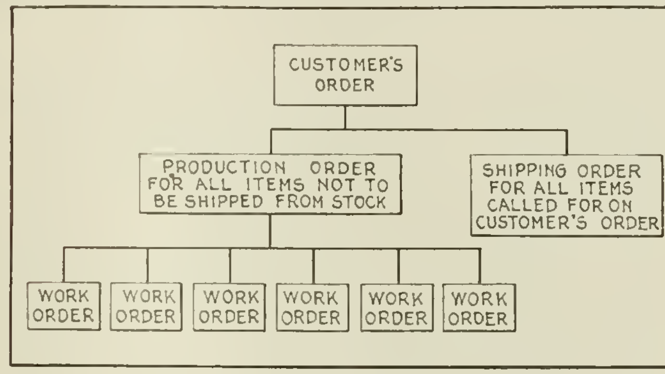

Fig. 4 Chart Showing Disposition of Customer's Order

In teaching this subject the lack of standardization of industrial terminology is an ever-present cross. Even the correct name for the subject itself is a matter of personal taste. Here it is called "Industrial Engineering." Another educator might call an identical course "Industrial Management," "Factory Management" or any of a score of titles. In one plant a certain form is called a "Material Issue," in another the same thing is a "Requisition." The first plant keeps an article in a "Store Room," the second keeps the same article in its "Stock Room." Standardization of nomenclature is certainly a goal worth the effort to achieve, and may the committee appointed for that purpose have all manner of success.

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Machine No.	Machine	Number of Machines	Area of One Machine	Present Value	Scrap Value	Life in Years	Total Area of Group	Floor Area Chargeable to Group	Hours Used per Month	Horsepower Rating	Horsepower-Hours	Power Cost for Group	Depreciation for Group	Hour Charge for Group	Space Charge for Group	Value Charge for Group	Total Charges for One Month	Hourly Rate for Group	Hourly Rate	Rounded Rate	Machine No.
1	Double Spindle Turret.	6	40	3800	1410	15	240	1281	1008	7.5	3780	37 00	121.90	30.96	83.54	438	711.40	423	.705	.71	1
2	14" Surface Grinder.	5	89.8	2400	890	15	449.4	2398	840	15	6290	61 60	65	25.80	156.47	230.50	539.37	3213	.643	.65	2
3	Lapointe Broach.	4	35.4	800	266	12	141.6	756	672	8	2680	26.24	22.90	20 60	49 42	61.50	180 66	1.075	.269	.27	3
4	Single Spindle Hartness.	11	40	3000	1130	15	440	2346	1185	5	2960	28.99	177 50	36 40	153.02	634.	102991	6 13	.557	.56	4
5	14" Fay Automatic Lathe	15	37.2	2500	928	15	558	2981	2520	7.5	9450	92 49	203	77.30	194 52	720	1287.31	7.66	.510	.52	5
21	Fellows Gear Shaper.	41	20.7	2675	802	10	849	4521	6880	3	10320	101.19	1050	203 20	295.02	2110	375941	22.39	546	.55	21
31	Trans Case Boring Mach	10	47.25	3000	900	10	4725	2521	1080	10	8440	82.29	287 50	51 20	164.52	577	1162.51	6.94	.694	.70	31
44	Universal Milling Machine	9	55	1650	612	15	495	2641	1512	5	3780	36.99	80 50	46.40	172.72	285 50	622 11	3 70	.411	.42	44
53	"Lo-Swing" Lathe	14	29.8	1440	635	15	417	2221	2352	10	11760	115.09	109 20	72.20	145 02	387	828 51	4 94	.353	.36	53
71	Butt Welder.	2	15	400	120	10	30	160	336	10	1680	16 49	7.66	10.30	10 45	15.38	60 28	359	.179	.18	71
72	Emery Wheel.	2	4 88	150	50	12	9 76	52.1	336	3	504	4 93	2.16	10.30	3 40	5.77	26.56	.158	.079	.08	72
74	Grinding Wheel	2	1 56	140	46.50	12	3.12	166	336	2	336	3.28	2	10.30	1.08	5.38	22.04	.131	.065	.07	74
	Bench.	17	16	50	5	15	272	1450	2790	–	–	–	4 58	85 40	94 50	16.32	200.80	1 195	.071	.08	B
												1283.00	398136	1500.00	3228 65	10,850.50	20,843.51				

Fig. 5 Type of Chart Used in Determining Machine Rates of the Various Machines in a Plant

Discussion

J. O. Keller[1] submitted a written discussion in which he called attention to the fact that Prof. Hugo Diemer had early recognized

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the importance of the propositions set forth in the paper, and as a consequence the course in industrial engineering at Pennsylvania State College, under his able direction, had comprised laboratory courses in time-study work, job routing, factory planning, etc.; and now included such courses in cost accounting, cost analysis, and production control.

His criticism of the course described by the author was that it was largely "cut and dried" and that not enough was left to the initiative of the students, most of his work consisting in the filling in of forms. The course, as he understood it, however, was somewhat limited in regard to time, and to cover so large a field rapidly and effectively some such procedure had probably been found necessary.

George H. Shepard[2] outlined the course in industrial engineering at Purdue University and pointed out that although developed independently, both it and the course at Cornell had evolved along the same lines. In the matter of time study he considered the setting of standard time only one of the objects to be sought. It was of at least equal importance to determine a correct method and to draw up a standard-practice instruction for it. In order that the engineer might be able to do this, it was essential that he should be able to make his own job analysis, and at Purdue they especially avoided giving to the student mimeographed sheets which enumerated the elements of each operation.

In all the work at Purdue emphasis was placed on principles. The characteristic methods of mass production were worse than useless to the jobbing and repair plant, and neither of them employed methods that could be applied to a department store. Yet department stores were beginning to seek industrially educated engineers to serve as the key men of their organizations. Management problems were infinite in their variety, and it was only by doing his own thinking on the basis of general principles that the manager could deal with them.

P. F. Walker,[3] who opened the oral discussion, said that the student training outlined in the paper was identical in many respects with work that was being developed under his supervision at the University of Kansas. It differed most in that in the latter institution an attempt was made to carry the student through the various commercial and business bases of the development of an industry. The points stressed were (1) the market and a sales policy for its development; (2) considerations affecting location of the plant in both general and local aspects; (3) the financial analysis of manufacturing enterprises of various types but with emphasis on machine building, on which the design was to be based. The aim was to plan an industry as to both its commercial and its physical aspects. He agreed with the author as to the value of such courses, for without experience in the actual laying out of plants and in making cost analyses the teaching of plant organization and production control lacked definiteness.

H. Wade Hibbard[4] said that he had three criticisms to offer. The first, which had already been mentioned by others, was on the use of mimeographed sheets which enumerated the elements of each operation to be studied and the time when each reading was to be taken. He believed that a student learned very largely by his mistakes and that everything should not be cut and dried for him. It was the bane of many a large engineering school that so much work of this kind had to be done. His second criticism was as to the use of lantern slides, which gave merely fleeting impressions that were forgotten by the student as soon as they passed off the screen. His third criticism was that the automobile transmission which was used as the basis of the student's mass-production problem was too complicated, and that the principles involved could be better taught by making use of examples of a simpler nature.

J. A. Shepard,[5] speaking from the viewpoint of a manufacturer, commended the cut-and-dried method because, if well devised, it seemed to him to be the most effective way of teaching the best methods to those at the beginning unfamiliar with manufacturing procedure. He stressed the importance of including in such instruction some consideration of the material-handling problems that entered in between the successive processes of production, in order that the student might not fail to provide for material-handling equipment in his building layouts.

F. B. Gilbreth[6] deprecated the use of the cut-and-dried method for the reason that it was wrong to teach students to repeat the mistakes of their predecessors. The time study that had been spoken of was a rule-of-thumb procedure because it determined how long it took to do work but did not determine the method. Time study could be eliminated so far as recording the facts was concerned by using a motion-picture camera for that purpose. Accuracy of time, to his mind, was of secondary importance as compared with accuracy of method. His firm had a very complete collection of films of operations performed by the best demonstration procurable, and these they would be glad to lend to educational institutions for instructional purposes.

John J. Long[7] thought that the cut-and-dried method of teaching could be defended on the ground that it brought to the attention of the untrained student's mind the best practice the instructor knew. Many of the problems of industry were not those of production alone, and he would like to see greater stress placed on the financial and administrative side of industry, particularly with reference to the small shop, for most American shops were those with a personnel of 100 or less.

Dexter S. Kimball[8] said that the thing that was cut-and-dried today might be a totally different thing tomorrow. For many years students at Cornell had been instructed in testing materials in the old way, each one making his own mistakes and repeating those of his predecessors. Then it was decided to make a change and an instructor was accordingly employed who was skilled in the use of the machine and who was able to demonstrate to the students just how a test should be made and how it should be recorded. This had been their practice for a number of years past and, so far as he knew, there were none who wanted to return to the old methods.

The author, in closing, said that he believed any engineer would admit that mass production as it existed today was not essentially a bad thing, and that no one would care to revert to the old handicraft civilization. It was a fact, however, that the problems of mass production were now involved in the instruction of large bodies of students, and he did not believe that the so-called cut-and-dried method was inherently bad. It had been his experience that a student left to himself had an infinite capacity for wandering around and not getting anywhere, and no matter how carefully cut and dried a problem might be, he would make enough of the mistakes that some thought were necessary for him to make in order to succeed as a student.

He was obliged to disagree with Professor Hibbard in regard to the complexity of the basis used in the mass-production problem. An automobile transmission was about the simplest mechanism that could be selected to use in teaching students real manufacturing methods, and in addition it was one with which students were fairly well acquainted. Further, he believed in using lantern slides, for when addressing students he felt it was much easier to make a lasting impression on their minds through the eye rather than through the ear.

He would not attempt to uphold the time-study work of the course in all its features, but it was proper to say that many to whom it had been given in the past had come back and told of the great benefit they had derived from it.

In regard to material handling, no definite laboratory or drawing-room work had been included in the course, largely because of time limitations. However, an endeavor was made to bring out the fact that the layout of a plant was governed largely by the sort of material-handling equipment required in the particular industry for which the plant was to be built.

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[3] Dean, School of Engineering, University of Kansas, Lawrence, Kan. Mem. A.S.M.E.

[4] Professor of Mechanical Engineering, University of Missouri, Columbia, Mo. Mem. A.S.M.E.

[5] Vice-president and chief engineer, Shepard Electric Crane & Hoist Co., Montour Falls, N. Y. Mem. A.S.M.E.

[6] Frank B. Gilbreth (Inc.), consulting engineers, Montclair, N. J. Mem. A.S.M.E.

[7] Industrial engineer, Schapiro & Schapiro, New York, N. Y. Assoc-Mem. A.S.M.E.

[8] Dean, College of Engineering, Cornell University, Ithaca, N. Y. Past-Pres. A.S.M.E.

The Thermal Conductivity of Liquids

Details Regarding Apparatus Employed in a Recent Investigation of the Subject—Difficulties Encountered in Making Tests—Radiation Corrections—Results Obtained and Conclusions Reached

By F. L. KALLAM,[1] LONG BEACH, CAL.

Although the thermal conductivity of liquids has been for a long time a favorite field of research for the physicist, it is still in a very undeveloped and unsatisfactory state. The subject is of profound importance in dealing with problems of heat engineering, and while the present investigation has not progressed far enough to yield definite conclusions, it has nevertheless resulted in the devising of apparatus which is believed to be suitable for obtaining the conductivity of liquids within a reasonable degree of accuracy.

In investigating the conductivity of liquids nothing more than relative values have been obtained, and even the method of arriving at results is often obscure. As early as 1800 Count Rumford showed the low conductivity of water by heating a tube at the middle of its length, boiling the water at the top by convection currents and leaving a chunk of ice at the bottom unmelted.

Despretz in 1838 made a series of experiments with a tin vessel full of hot oil kept at constant temperature floating on the surface of water in a large container, and a series of thermometers one below the other in a containing vessel. In this manner he found that the conductivity of heat in liquids obeys the same laws as in solids, but is much less pronounced. Bottomley in 1881, using a modification of Despretz' method, poured hot water on the top of a mass of water nearly filling a cylindrical wooden tank. Readings were taken from time to time of two thermometers one a little lower than the other, which gave the difference of temperature between the two sides of the intervening stratum, and the quantity of heat conducted in a given time through this stratum was obtained from readings of the temperature of the whole mass of water below on an upright thermometer with an exceedingly long cylindrical bulb extending downward from the center of the stratum in question nearly to the bottom of the vessel. The value for conductivity as determined by this method varied from 5.8 to 6.67 (English units).

Guthrie examined the conductivity of liquids by using two hollow brass cones placed near together, the top of one pointing upward, that of the other downward. The distance separating the bases could be regulated and the liquid to be examined was introduced between them by means of a pipette. The base of the upper cone was kept at a constant temperature by a current of hot water, and the lower cone was converted into an air thermometer by simple methods. By varying the distance between the bases of the cones as well as the liquids introduced between them, and noting depressions of the air thermometer, a measure of the resistance to the passage of heat of different liquids was obtained.

Weber in 1880 used two small copper disks separated by pieces of glass, the space between the disks being filled with liquid; the lower disk was laid on a smooth block of ice whose temperature it rapidly assumed and measurements were made of changes in temperature of the upper disk with a thermoelectrical arrangement. Lees employed the same method with some refinements, but used an ebonite ring to enclose liquid between the disks. On the whole, nothing definitely satisfactory seems to have been developed hitherto in the way of apparatus or experimental methods for the determination of the true conductivities of liquids.

Mathematical Expression for Thermal Conductivity

When convection is eliminated, the formula embodying the coefficient of thermal conductivity may be deduced in the same manner as for solids.

If Q = B.t.u. flowing per square foot per hour

$T_1 - T_2$ = temperature drop in deg. fahr. between two planes cutting the liquid parallel to each other, and perpendicular to the direction of flow

A = area of section through which heat flows, sq. ft.

S = time of flow in hours

L = depth of liquid or perpendicular distance between two planes, in.

k = conductivity of the liquid in B.t.u. per sq. ft. per in. per deg. fahr. per hour

then

$$Q = \frac{k(T_1 - T_2)AS}{L} \quad \text{or } k = \frac{QL}{(T_1 - T_2)AS}.$$

If it is assumed that k is a straight-line function of temperature, the mean conductivity between any two points is the arithmetical mean of the conductivities at these temperatures. But throughout

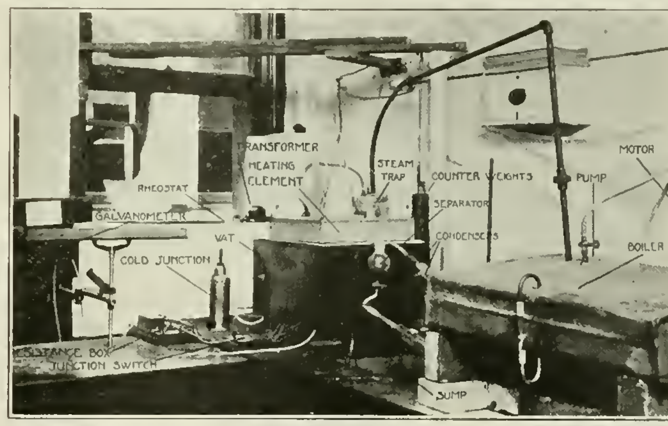

Fig. 1 General View of Apparatus Used by Author in Investigating the Thermal Conductivity of Liquids

this investigation K the mean conductivity is taken as k for the sake of simplicity.

Principles of the Apparatus

In studying thermal conductivity, convection currents must be eliminated. Therefore it is quite certain that the liquid to be tested must be heated at the top.

The material of the container must have a lower conductivity than that of the liquid to be tested or heat will be transmitted through the walls of the vessel faster than through the liquid, and this will lead to convection currents. Hence a material such as wood must be chosen for the container.

The quantity of heat transmitted to the liquid must be known and this would be readily obtainable by supplying the heat from steam at atmospheric pressure and measuring the amount of steam condensed. Hence the use of a steam heater follows. To avoid the complication of radiation losses, the heater must be jacketed with steam at the same pressure and temperature except where it is in contact with the liquid to be tested, so that all the heat released by condensation will pass into this liquid.

Temperatures must be known at different strata instantaneously, and with the strata close together thermometers are eliminated not only on account of lag but because of mechanical difficulties.

The apparatus is based on these principles and the method employed may be briefly described as follows:

The liquid to be tested is placed in a vat, which is itself a poor conductor and which contains thermocouples at known strata.

[1] Mech Engr., Shell Co. of California. Jun. Mem. A.S.M.E.

Abstract of a thesis submitted by the author in June, 1922, to the Department of Mechanical Engineering and Committee of Graduate Study of Leland Stanford Jr. University in partial fulfillment of the requirements for the degree of Engineer. Awarded A.S.M.E. Junior Prize for best paper during 1922.

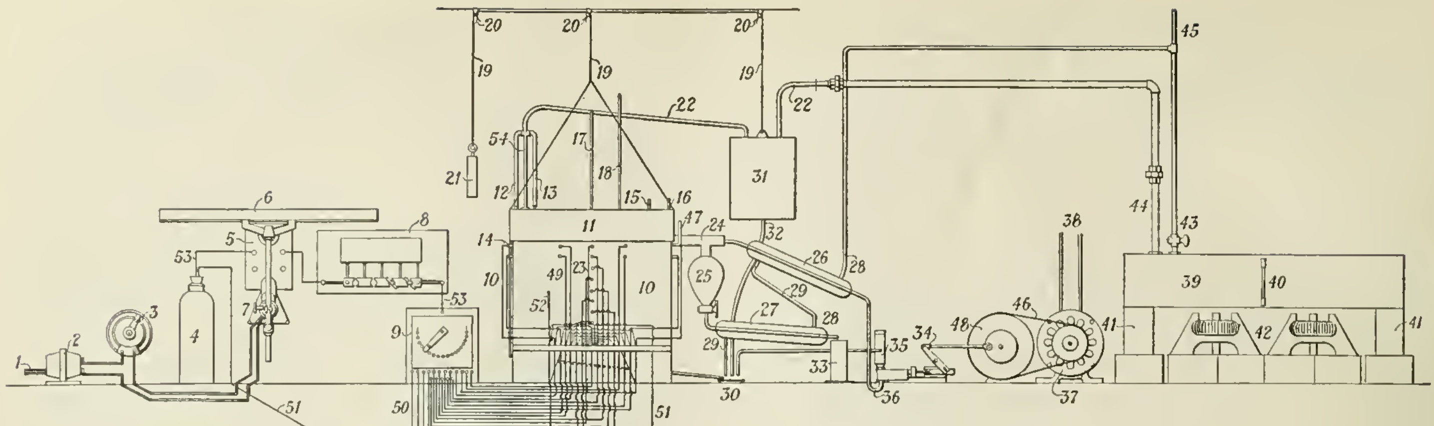

Fig. 2 Diagram Showing Arrangement of Author's Apparatus for Determining the Thermal Conductivity of Liquids

1 110-volt a.c. main
2 Bell transformer
3 Rheostat
4 Thermos bottle—cold junction
5 Paul galvanometer
6 Galvanometer scale
7 Galvanometer light
8 Resistance box
9 Junction switch
10 Vat, jacket removed
11 Heating element
12 Jacket intake
13 Bath intake
14 Jacket drain
15 Bath exhaust
16 Jacket exhaust
17 Bath thermometer
18 Jacket thermometer
19 Elevating cord
20 Pulley
21 Counterbalance
22 Flexible steam line
23 Thermocouples
24 Bath drain—magnesia covered
25 Steam separator
26 Steam condenser
27 Condensate cooler
28 Intake cooling water
29 Discharge cooling water
30 Sump
31 Steam separator
32 Steam - separator drain
33 Condensate graduate
34 Pump
35 Pump discharge
36 Pump suction
37 Single-phase motor
38 110-volt a.c. main
39 Boiler
40 Water glass
41 Brick supports
42 Gas burners
43 Feedwater
44 Steam main
45 Water supply
46 Driving belt
47 Level glass
48 Driving wheel
49 Copper and iron-constantan leads from hot junctions
50 Constantan leads
51 Copper neutral lead
52 Free thermocouple No. 11
53 Neutral constantan lead
54 Support

Heat is supplied to the surface of the liquid by means of a steam-jacketed bath, the vapor being at atmospheric pressure. The amount of heat liberated is determined from the condensate collected. Hence, knowing the vat dimensions, the temperatures at different strata, strata depth, and heat generated, all for the same period of time, the thermal conductivity is readily obtained from the formula

$$K = \frac{QL}{(T - T_2)AS}$$

Description of the Apparatus

The apparatus is illustrated in the views and diagrams of Figs. 1 to 4, inclusive.

Temperature Measurement. Avoiding thermometers of special and complicated construction, thermocouples of copper-constantan were employed, the junctions being welded into the form of a bead. To support these junctions at the proper locations within the vat, the couples were run through a $^1/_8$-in. glass tube, care being exercised to make a good seal between the wire and the glass. A direct-reading galvanometer of the R. W. Paul reflecting type was found to be a simple and effective measuring instrument. The thermocouples were arranged in the center at intervals of approximately 1 in. from top to bottom of the 7 in. depth of the vat. At the point of contact of heater and liquid five couples were used, and the same number at 1 in. lower depth. From this point to the bottom only one couple at each level was used. A seventeenth couple, not fixed as to location, was used to explore temperatures of the container. As it was impossible to place the junctions exactly one inch apart and it was necessary to measure accurately the actual distances, a single cold junction was provided for the seventeen couples and suitable connections were made so that each couple could be put in series with the galvanometer at will.

Calibration was made in place, with the cold junction kept at 32 deg. fahr. and the water in the vat heated by means of two electric heaters. To make the temperature in the vat uniform the water was agitated with a paddle. Throughout the investigation the cold junction was kept at 32 deg. fahr. by the use of cracked ice within a thermos bottle.

The Vat. The vat containing the liquid to be tested is constructed of $1^1/_4$-in. redwood, with a cross-section of exactly one square foot for facility in calculation. Holes are provided for the insertion of thermocouples at vertical intervals of 1 in. The bottom tapers to a drain plug at the center.

Calked joints and waterproof coatings are provided to secure perfect watertightness. A small glass tube is used to see that the water in the vat is always at the proper level. It was thought that the vat was suitably constructed to prevent excessive radiation losses, but it was ultimately found necessary to enclose it in a radiation jacket, in the form of a slightly larger second wooden box so as to provide a dead-air space around the vat proper.

The Heating Element. As shown in the figures, the heating element consists of two parts, the heater or bath proper and a jacket. The heater is exactly 1 ft. square so that it fits snugly into the vat. The entire heater and the surface in contact with the water is of copper, used because of its high conducting power. The heating surface is not exactly flat but is somewhat dished outward, for the purpose of forcing out any air which might otherwise be trapped between the vat and the heater when the latter is first placed in contact with the liquid. The dished bottom also serves as a sump for all steam condensed. A $^1/_8$-in. brass tube having a right-angle turn is so placed within the heater that it dips down to the bottom of the sump. The end of this tube is flared, with four notches cut in its edge, thus affording what might be termed "feet."

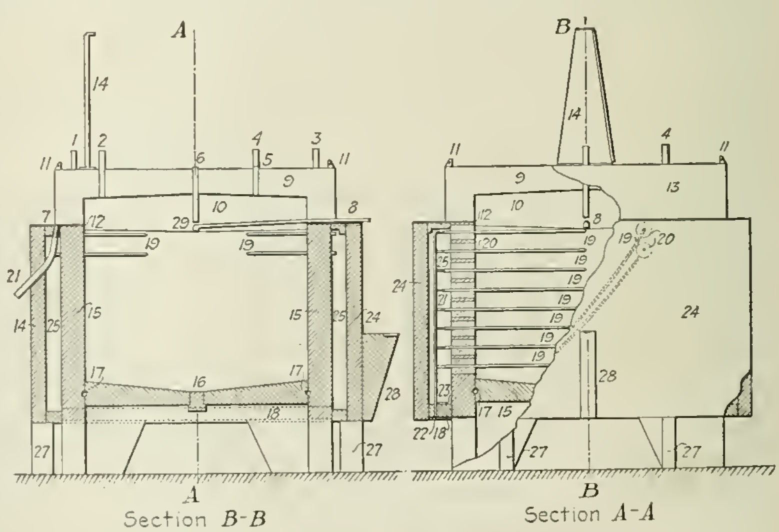

Fig. 3 Details of Heating Element, Vat, and Jacket

1 Intake to heater jacket
2 Intake to steam bath
3 Exhaust from heater jacket
4 Exhaust from steam bath
5 Jacket thermometer cup
6 Steam-bath thermometer cup
7 Jacket drain
8 Steam-bath drain
9 Galvanized-iron jacket
10 Steam bath
11 Clips for supporting bath and jacket
12 Asbestos packing
13 Heating element, jacket, and bath
14 Support for steam line
15 Redwood vat
16 Drain plug
17 Recessed butt joint
18 Thermocouple lead board
19 Glass-encased thermocouples
20 Rubber stoppers
21 Leads from couples to lead board
22 Leads to junction switch
23 Neutral lead to cold junction
24 Redwood radiation jacket
25 Dead air space
26 Drain from heater jacket
27 Jacket supports
28 Support for steam-condensate separator
29 Pump suction

These are soldered to the dished copper bottom, which leaves four openings in the tube. The latter rises $^1/_4$ in. and then runs parallel to the heater bottom, passing out at the side at the same elevation. Thus, by applying suction at this outer end, the condensate within the heater may be removed. The arrangement of the heater can be studied more closely in the figures. It should be noted that the bottom of the heater is free from the jacket, projecting down into the liquid for good contact. The steam line is divided, part going into the heater and part to the heater jacket. A suitable steam separator is provided at the lowest point in the steam line and as close to the heater as possible. In using the apparatus it is necessary to have the heater and jacket fully heated at the start of the test, hence steam cannot be passed through the heater when it is in contact with the liquid to heat the metal up to working temperature. To facilitate such heating, both the trap and heater are suspended by cords over pulleys and attached to the same counterbalancing weight. Thus they may be readily removed from the test position to a location where they may be heated without affecting the liquid to be tested.

The Condensate Separator. In removing the condensate from the heater there is a possibility of some steam being taken along with it. As the condensate proper is a measure of the heat put into the liquid tested, it must not be contaminated with free steam which has been condensed after leaving the heater. For this purpose a separator is placed as close to the heating jacket as possible. This is nothing but a tee made of glass tubing, with the third leg vertical and connecting directly to a glass chemical separating funnel. The entire tee is covered with magnesia. By means of this tee any steam drawn over passes over the third leg and passes on to the condenser and pump, while the condensate proper, being of greater density than the steam, flows into the third leg of the tee and on to the funnel, where it collects. Suction must not be applied too rapidly or else the condensate will skip the third leg and take the steam route. Before collection in a calibrated vessel the condensate is cooled to prevent possible evaporation due to its high temperature.

Manipulation of the Apparatus

In starting a test the heating element is raised and steam passed through the system. This is continued until both the jacket and bath thermometers indicate 212 deg. fahr. Any steam condensed in the heater must be completely removed, and for this purpose an atomizer was found to give the best results. The vat must be completely filled with liquid, so that when heater is lowered in contact with it, some of the liquid will be forced over the top. This insures good surface contact with the heater. With the heater in contact with the liquid, the test starts. The separator must be instantaneously connected to the heater and the two condensers put into operation. Just prior to placing the heater in contact with the liquid, initial readings on the 17 couples, the two heating-element thermometers, the room-temperature thermometer, and the graduated condensate vessel must be taken.

Difficulties in the Tests

A large number of tests were made but only three are recorded in the report of the investigation, the others being discarded because of such difficulties as inability to maintain constant temperature due to lack of steam, leakage at the entrance of the glass thermocouple, tubes, and short-circuiting of the thermocouples. The vat rapidly deteriorates and at the end of a certain time becomes unfit for use. Blisters are formed on its exterior coating due to water which seeps from the interior. This is a sign that the vat is becoming waterlogged and the temperature of the liquid under test ceases to increase because water flows through the sides of the vat in small streams. Hence in using a wooden container some preparation must be applied to the interior which will prevent the liquid from coming in contact with the wood. No suitable material has yet been found, and the only remedy is to dry out the tank for two weeks when it becomes waterlogged. Intermittent working of the suction pump must be avoided, and other minor difficulties are inescapable.

Radiation Corrections

Even when the vat is jacketed, corrections must be applied to cover radiation losses. To secure these corrections the following procedure is employed: The water in the vat is heated to the boiling point and a calibrating lid is placed in position; this lid is merely a cover of the same material as the vat, through which five thermometers project into the water. Temperatures are taken from time to time, and the temperature of the bath is plotted against time. From this curve the rate of cooling at different temperatures of the vat is obtained, measured in degrees of drop per hour. The readings of the thermocouples are appropriately corrected for this drop when computations are made. The corrections are not absolutely accurate, since in determining radiation losses the temperature of the water in the vat is uniform, whereas in the conductivity tests there is a temperature gradient. The correction is of course always added to the readings of the thermocouples.

Computations

The data obtained in the three final tests are elaborately set forth in the report in tables and curves where temperatures at various depths are plotted against time. It is only after three hours of testing that the temperature difference between strata tends toward uniformity. For this reason the temperatures corresponding to

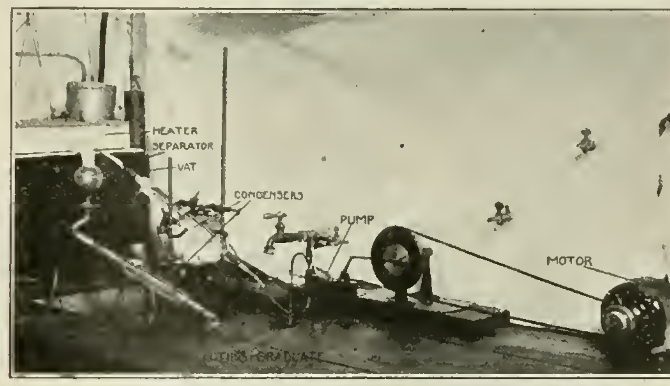

Fig. 4 View of Part of Apparatus with Boiler Removed, Showing Pump and Motor

3, 4, 5, and 6 hours are selected and arranged in a special table (Table 1) after corrections have been made for radiation losses.

From Table 1, temperature is plotted against the depth for con-

TABLE 1 INSTANTANEOUS TEMPERATURES AT VARIOUS STRATA

(From corrected temperature data of tests Nos. 2 and 3; temperatures in deg. fahr.)

Strata	L, in.	Time, hr.	T_1	T_2	$T_1 - T_2$	Avg. T
B-C	1.25	3	180	130	50	155
		4	186	141	45	163
		5	190	147	43	168
		6	192	152	40	172
B-D	2.06	3	180	107	73	143
		4	187	117	70	152
		5	190	127	63	158
		6	192	130	62	161
B-E	3.19	3	180	85	95	132
		4	186	97	89	141
		5	190	103	87	146
		6	191	108	83	149
B-F	4.13	3	180	80	100	130
		4	186	86	100	136
		5	189	90	99	139
		6	191	94	97	142
B-G	5.01	3	181	76	105	128
		4	186	79	107	132
		5	189	82	107	135
		6	192	86	106	139
B-H	5.95	3	180	77	103	128
		4	186	78	108	132
		5	190	80	110	135
		6	191	82	109	136
C-D	0.81	3	131	107	24	119
		4	140	117	23	128
		5	147	125	22	136
		6	153	131	22	142
C-E	1.94	3	131	88	43	109
		4	140	96	44	118
		5	147	103	44	125
		6	152	109	43	130
C-F	2.88	3	131	80	51	105
		4	139	85	54	112
		5	146	90	56	118
		6	151	96	55	123
C-G	3.76	3	130	77	53	103
		4	140	80	60	110
		5	145	82	63	113
		6	153	87	66	120
C-H	4.70	3	130	77	54	104
		4	140	78	62	109
		5	147	81	66	114
		6	152	83	69	117
D-E	1.13	3	105	88	17	96
		4	117	96	21	106
		5	127	103	24	115
		6	133	109	24	121
D-F	2.07	3	107	80	27	93
		4	118	85	33	101
		5	126	91	35	108
		6	132	96	36	114
D-G	2.95	3	106	77	29	91
		4	117	79	38	98
		5	125	83	42	104
		6	132	86	46	109
D-H	3.87	3	106	76	30	91
		4	117	78	39	97
		5	125	80	45	102
		6	131	82	49	106
E-F	0.94	3	88	81	7	84
		4	96	85	11	90
		5	103	90	13	96
		6	109	96	13	102
E-G	1.82	3	87	75	9	82
		4	96	78	13	89
		5	103	83	12	92
		6	109	91	10	104
E-H	2.76	3	88	76	19	82
		4	97	78	22	82
		5	104	82	22	87
		6	109	83	26	96
F-G	0.86	3	79	77	2	78
		4	84	79	5	81
		5	89	82	7	85
		6	95	86	9	90
F-H	1.80	3	79	63	3	77

Note.—*B* is located 0.81 in. below the heater.

stant times as shown in Fig. 5 for the second and third of the three tests accepted by the author. The area under these curves must represent the total heat put into the liquid up to the time in question, since the ordinates represent degrees and the abscissas volumes of water, which can be converted into weight by multiplying by the density corresponding to the average temperature. This obviously gives the heat required to raise a mass of water a certain number of degrees in a given time. Thus the area included between the

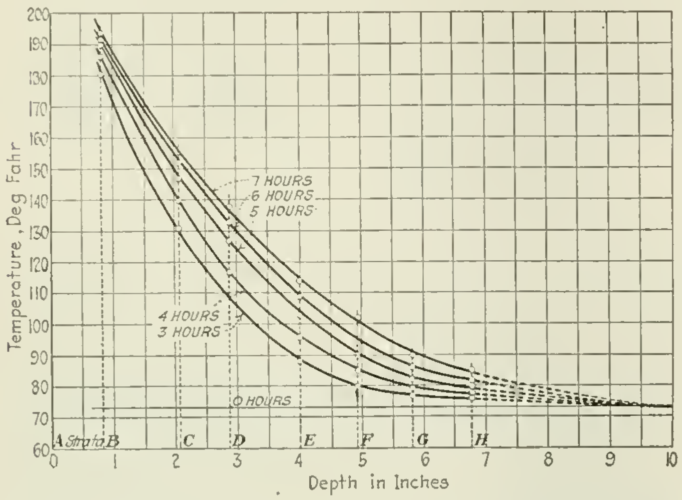

Fig. 5 Total-Heat Curves Relating Temperature, Depth, and Time

(Tests Nos. 2 and 3. Computed for a temperature gradient of $(T_1 - T_2)/L = 17$ to 24.)

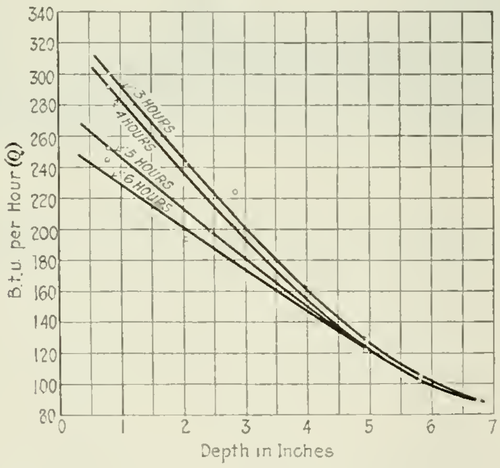

Fig. 6 Heat-Flow Curves Derived from Total-Heat Curves Where $(T_1 = T_2)/L = 27$ to 24

3-hr. and 4-hr. curves is the amount of heat put into the liquid between the third and fourth hours of the test.

In this connection, it will be noticed that the curves of Fig. 5 are extended past their lowest temperature point down to the initial temperature of the water by continuing them smoothly with dotted lines. The author believes that this assumption will yield more nearly correct results than can be obtained by stopping the curves at the lowest temperature reading.

By taking the area between any two time curves starting at any desired depth and planimetering the area for the remaining depths, the heat-transfer rate at the initial depth is found in B.t.u. per hour. This gives Q in the formula direct. Fig. 7 derived in this manner gives the heat-transfer rate at each of the desired strata for the representative tests 2 and 3.

As regards the unit of heat corresponding to a given area in Fig. 5, one inch along the axis of abscissas represents a rise in temperature of 20 deg. fahr. One inch along the axis of ordinates represents 1 in. of depth, which is equivalent to $^1/_{12}$ cu. ft. of water inasmuch as the vat has a surface of 1 sq. ft. From this it follows that 1 sq. in. of area represents 104 B.t.u.

Although some corrections have been made in these curves for radiation losses, a further correction should be made by comparing the rate of heat delivered to the liquid in the vat with the rate of supply from the steam condensed—which may readily be computed from the weight of condensate and the latent heat at the given pressure. The condensate method gives approximately 1.16 times the total heat that the graphical method does and values of conductivity should be multiplied by 1.16 accordingly.

After this work has been performed it is possible to determine the thermal conductivity K from the previously developed expression

$$K = \frac{QL}{(T_1 - T_2)AS}$$

For example, we shall compute K for tests 2 and 3 between strata B and F, the distance between the two being 4.13 in. Also we desire K at the end of 3 hr., at which time T_1 = 180 deg., T_2 = 100 deg., and Q, the rate from the curves of Fig. 6 for 3 hr., is 300

(Continued on page 511)

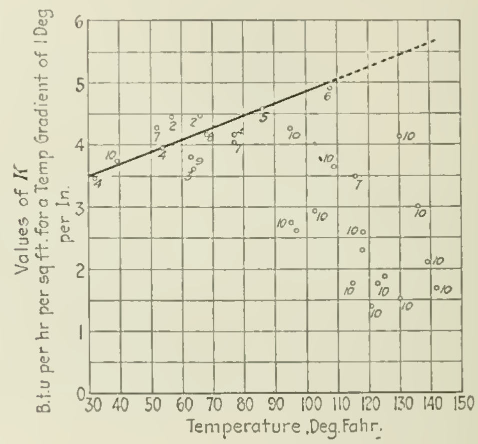

Fig. 7 Variation of Thermal Conductivity of Water with Temperature

(Authorities: 1, Wachmuth; 2, Winklemann; 3, Chree; 4, H. F. Weber; 5, Graetz 6, Lundquist; 7, Lees; 8, Milner and Chattock; 9, R. Weber; 10, Present test.)

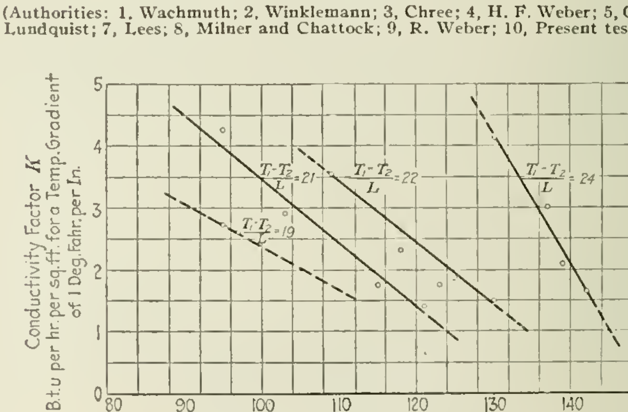

Fig. 8 Variation of Thermal Conductivity of Water with the Temperature Gradient

(K found from $QL/(T_1 - T_2)AS$; $T_1 - T_2$ = temperature drop in deg. fahr. between lamina faces; L = perpendicular distance in inches between lamina faces.)

TABLE 2 VALUES OF K COMPUTED FROM TESTS

Test Nos.	Strata	Time S, hr.	T_1	T_2	$T_1 - T_2$	L	$\frac{T_1 - T_2}{L}$	Q	Avg. T	K
2 & 3	B-F	3	180	80	100	4.13	24.2	300	130	4.13
		4	186	86	100	4.13	24.2	292	136	3.01
		5	189	90	99	4.13	24.0	252	139	2.10
		6	191	94	97	4.13	23.6	235	142	1.67
2 & 3	C-E	3	131	88	43	1.94	22.2	242	109	3.64
		4	140	96	44	1.94	22.7	235	118	2.59
		5	147	103	44	1.94	22.7	212	125	1.87
		6	152	109	43	1.94	22.2	200	130	1.50
1	C-F	3	124	67	59	2.88	20.5	265	95	4.25
		4	134	73	61	2.88	21.2	248	103	2.92
2 & 3	D-E	5	127	103	24	1.13	21.2	186	115	1.75
		6	133	109	24	1.13	21.2	178	121	1.40
1	D-E	4	106	84	22	1.13	19.4	214	95	2.74
1	D-F	5	116	79	37	2.07	18.9	235	97	2.63
1	C-G	6	155	82	73	3.76	19.4	270	118	2.32
2 & 3	C-F	6	151	96	55	2.88	19.1	201	123	1.75

Sectionalization and Remote Control of High-Pressure Steam Lines

By PETER PAYNE DEAN,[1] STAMFORD, CONN.

This paper is intended to bring out need of protection other than that of hand-operated valves for high-pressure steam lines in case of failure of pipe or fittings, and deals with the remote operation of various types of valves by electric motor or steam piston in order to quickly and safely stop escaping steam. It is based on a careful study of valve construction and methods of power operation made by the author during the last few years, and on experience gained with a large number of electrically operated valve installations which he has designed and placed in practically all of the important power-generating stations in the country, and gives particulars regarding the construction of various protective devices, valves, and motor-control systems that are available.

STEAM pressures as high as 350 lb. per sq. in. with 700 deg. fahr. total heat are now frequently encountered, and no doubt 500 lb. will soon be standard practice. Under such pressures every piece of valve, piping, and fitting metal will be subjected to an excessive strain, which, when coupled with high temperature, may produce a result akin to metal fatigue, about which we have very little knowledge and even less experience. Further, no safe standard has been universally adopted for 500-lb. steam fittings, bolts, flanges, expansion loops, etc., but this will very probably come after more exhaustive time tests.

The protection of human life, however, should be the first consideration, and after that, continuity of plant operation and protection of property; and surely all will agree that protection beyond that found in the average plant is necessary. We can only make every attempt to prevent failure by careful design, and then provide, as a matter of safety, the best possible safeguard if it does happen. Those who were present at the tests made at the Essex power station of the Public Service Co., Newark, N. J., on January 28, 1922, and watched the spectacle of high-pressure steam calmly blowing to atmosphere at a velocity of over six miles a minute, do not need to draw much upon their imaginations to visualize the damage that such a discharge would do in a boiler or turbine room.

Location of Master Valves

The master valves should be those nearest the boiler, and either the automatic stop checks or gate valves in the boiler lead. Valves at this point protect the complete piping system and would not be affected by mechanical movement of a broken line, which would possibly throw excessive strain on a gate valve, causing it to jam. Automatic stop-check and boiler-lead gate valves are seldom above 10 in. in diameter and without doubt can be closed in from fifteen to thirty seconds, so that any or all of the boilers may be cut out at will.

Unless all the boilers are isolated there would be a reverse flow from the header back through the break, so that a master valve is also necessary in the boiler lead at the header, which in any event is usually included. Closing both the boiler-lead valve and this last-mentioned valve completely isolates one boiler.

Boiler-lead valves are suggested for three very good reasons:

a They protect the whole system of piping from the superheater and are well located for power operation

b If a bad fracture should occur, it would be almost useless to endeavor to locate it and sectionalize the header to stop the flow, on account of the tremendous volume of condensed steam and consequent confusion

c There is no certainty whatever that header valves above 12 or 14 in. in diameter will close under open-end conditions on account of their construction to withstand such strain.

The principal argument against emergency closing off of the boilers is that the plant would be completely shut down. In the author's opinion, if a bad break occurs its location cannot be determined until almost the entire steam supply is stopped. As soon as the break is located, the sectionalizing valves may be brought into play and the boilers quickly brought back on the line.

Even though large header valves can be closed from a distance, the author nevertheless believes that the quick and safe way is to shut off the boilers in sections until the break is stopped. Incidentally, with any remote-closing scheme the boiler safety valves should be piped to a header and blown to atmosphere, as in the event of a boiler shutdown they would all blow together. Some arrangement also of an auxiliary header should be worked out to supply the boiler-feed pumps, as well as a scheme for shutting down the draft fans. Power-operated header valves of large diameter may be depended upon to stop a very bad fitting blow or gasket leak, so for this reason and also for convenience of operation they should be provided with remote control.

To close an 18-in. high-pressure gate valve requires two men

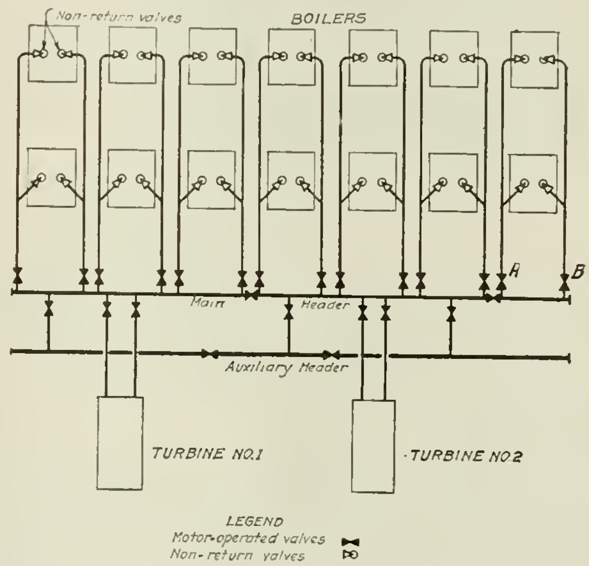

Fig. 1 Boiler and Piping Layout of a Power Station in Which Electricallly Operated Valves are Employed
(Colfax Station, Duquesne Light & Power Co., Pittsburgh, Pa.)

for a period of at least fifteen minutes, including transit to and from the valve, not to mention the physical effort necessary and the danger of penetrating a steam-laden alley with very uncertain conditions under foot. Great care is taken to see that main-line valves are tested for tightness and that they are strong and rugged, presumably for assurance that they will not fail during operation or when an emergency arises. Who knows, however, whether they can be even reached in case of trouble? Therefore, why not turn them into real protective devices by providing remote control? It should not take much of an argument to convince those in charge of expenditures that is worth the money.

Fig. 1 shows a typical existing boiler and piping layout in which electrically operated valves are employed. Complete isolation of one boiler from the line may be made by closing any pair of valves *A*, *B*, either singly or from one switch, but this of course leaves the boiler-lead lines unprotected. Further protection may be accomplished by electrically operating the non-return valves shown and closing them together with valves *A*, *B*, in order to prevent reverse flow from the header.

Fig. 2 shows a similar system wherein the boiler-lead valves may be closed separately and the main and branch-header valves used for sectionalizing.

[1] Payne Dean Ltd. Mem. A.S.M.E.

Contributed by the Power Division and presented at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, of The American Society of Mechanical Engineers. Abridged. All papers are subject to revision.

Remote-Control Location

Since any remote-control system must of necessity be electrical, the design and placing of a central switchboard must be carefully thought out. The location should be as near the main means of exit as possible as plant operators in case of trouble will move toward this point. With the open air in view, a man is more apt to regain his composure and presence of mind than when called upon to act hurriedly and then bolt for his life.

Such stations should never be placed in steamproof vaults adjacent to the boiler room and without means of safe exit. They will be useless in emergencies as the operators will not travel in that direction.

The operation of switches to shut the valves should be as simple

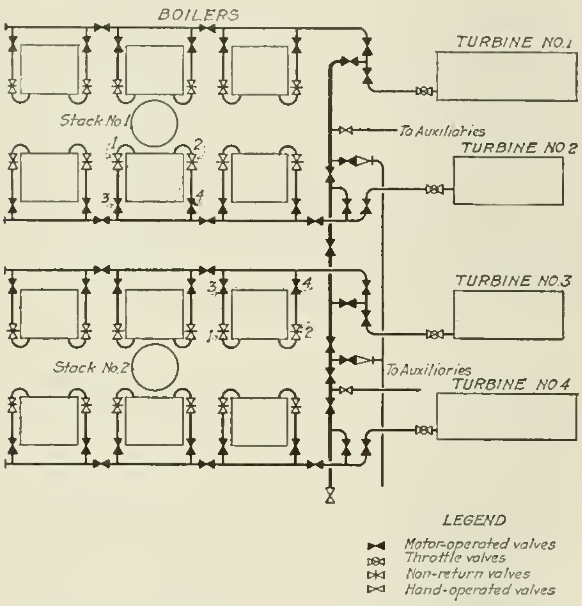

Fig. 2 Boiler and Piping Layout in which the Boiler-Lead Valves May be Closed Separately and the Header Valves Used for Sectionalizing

(Hell Gate Station, United Electric Light & Power Co., New York.)

as possible, preferably by breaking a protective glass window and pushing a button.

Under no consideration is it safe to open master valves from a remote point which may be opened locally, either by hand or electrically. In order to allow the operator to see exactly what he is doing, the face of the valve-control switchboard should be provided with a plainly marked miniature representation of the complete station piping, with push buttons to represent the valves. Red and green indicating lights should be provided to show whether the valves respond and to show the general position of the valves in the complete system.

Types of Master Valves

There are two types of quick-acting valves, the straight triple-duty, and the piston-operated trip valve, both of which are of the globe type. The former is a combination of non-return, stop and "automatic closing on drop of line pressure," performing therefore the three duties. Engineers have not taken kindly to line protection upon drop of pressure; therefore the third duty is operated by an electrically controlled pilot valve admitting steam on top of the closing cylinder. Such a valve and its auxiliary pilot are shown in Fig. 3. This valve depends upon the excess-area piston forcing the disk to its seat against the pressure.

The straight trip valve closes with the pressure and is remotely operated by a solenoid magnetic latch. It is used mostly as an additional emergency turbine stop upon overspeeding, being placed in the turbine lead between the header and throttle trip valve. On account of its somewhat complicated construction, it is hardly suitable for line protection. The triple-duty remotely controlled valve would seem to be the logical type for quick closing, provided that it can be made to close against the extreme velocity which would result with an open-end line blowing to atmosphere and would possibly reach 50,000 ft. per min., depending upon the friction loss in the pipe between the header and the boiler. The action in this case would not be that of a non-return automatic check valve which actually closes due to the reverse flow, but the disk would be forced on to its seat against an extreme velocity in the opposite direction and the action would be somewhat akin to that of stopping a high-pressure nozzle with one's finger. Valves of this description are generally closed by pressure being admitted to the top of the excess-area piston, but test data on closing under extreme velocity conditions do not seem to be available, and until they are, much cannot be said.

A high steam discharge is very apt to carry over slugs of water, and there may be some doubt as to the advisability of instantly closing a valve under this condition. It would seem that a closing time of ten to fifteen seconds would be safer.

Motor-Operated Non Return Valves

Electrical operation of non-return valves was first suggested by the author and has been adopted by many leading engineers. The operation is the same as that required on the triple-duty design, with the exception that the valve stem is driven by a motor provided with reduction gearing, as shown in Fig. 4. Their action under most extreme conditions is positive, provided that the motor control is of the proper design and application. The valves are ideally located with respect to line protection, being directly at the superheater outlet and where vibration due to the whip of a broken boiler lead would not be excessive on account of the valve being securely anchored. They close easily under normal conditions, and for emergency closing should be provided with ball thrust bearings to eliminate the closing friction as much as possible. The control unit should be bolted directly to the yoke and geared to the stem through the yoke nut, which is of the rising-stem type. The travel of the disk is not more than one-quarter of its diameter, so that quick closing is possible. Although ruggedly built this valve will not stand much jamming, and therefore calls for a special type of motor control to prevent it.

There is only one safe point of closing, and that is when the disks and seats are in perfect contact; to effect this the motor drive should have an automatically operated mechanical clutch completely disconnecting the high-speed armature and gears from the motor at the moment of closing, thus eliminating its momentum and allowing the motor armature to freely come to rest. Without this clutch the limit switch must be set to stop the motor before the valve reaches its seat, and a certain amount of drift due to the momentum of the armature and gears must be depended upon to seat the valve.

This drift depends upon the resistance to closing, which distinctly varies with line conditions; for instance, when the valve is closed with balanced pressure and there is no flow in the boiler-lead line, there is no resistance to the disk and the electrical limit must be set to trip just at the point of closing so that the disk can drift into its seat.

Assume, then, an open-end pipe condition with steam blowing to atmosphere during which the disk encounters excessive resistance. The moment the electrical limit opens, the velocity will overcome the momentum and act as a brake, thus causing the motor to stop instantly and before the valve is actually seated.

The non-return or globe valve must seat tightly and has no leeway to travel as has a gate valve. Therefore it should be made to seat tightly under all conditions and without jamming or strain.

Types of Gate Valves

The Essex station tests showed that valves of this description up to 10 in. in diameter may be safely closed under emergency conditions, and from a careful study of their behavior it seems safe to recommend them for line protection up to 12 and 14 in. in diameter. Data on emergency closing of valves of above this size and up to 22 in. are not available and the safest construction would be to machine the guides, provide the yokes with ball bearings, and attach a control unit of extra large capacity. Valves of this size are used generally for line sectionalizing, and no attempt should be made to close quickly. A typical electrically operated boiler-lead valve is shown in Fig. 5.

Table 1 shows the speeds of closing recommended under various

TABLE 1 SPEEDS RECOMMENDED FOR CLOSING HIGH-PRESSURE STEAM VALVES UNDER VARIOUS CONDITIONS

(Based on valves provided with ball bearings and machined guides. Maximum steam pressure, 350 lb. per sq. in.)

Gate Valves (Under emergency conditions, full blow to atmosphere):						
Size, inches	4	6	8	10	12	14
Type of Dean unit used	M3	M3	E1	E2	E2	E2
Closing time, seconds	20	30	30	30	45	60
Gate Valves (Under normal operating conditions, steam velocity not exceeding 15,000 ft. per min.):						
Size, inches	16	18	..	..	..	..
Type of Dean unit used	E2	E2	..	..	..	..
Closing time, minutes	2	3	..	..	..	..
Automatic Stop and Check Valves and Globe Valves (Emergency conditions):						
Size, inches	6	8	10	12[1]	14[1]	..
Type of Dean unit used	M3	E1	E2	E2	E2	..
Closing time, seconds	30	30	30	45	60	..

[1] Closes with pressure.

conditions that have been standardized by most of the valve manufacturers.

For emergency closing with an unknown direction of steam flow in the line, there seems to be little choice as to the type of gate-valve construction between the solid-wedge taper seat, the split-wedge taper seat, and the parallel-seat Hopkinson type. A valve of each type was tested at Essex station and examination showed that none of them was excessively affected by the strain.

For steam lines with one direction of flow, such as boiler and turbine leads, the Borsig type is particularly well adapted as the steam flow assists in closing and against a minimum of friction. It has the advantage of minimum pressure drop on account of the straight opening and may be quickly closed by motor operation up to large diameters. The motor-control apparatus need be only of sufficient capacity to open the valve under balanced conditions. This type is used extensively abroad in place of globe valves and a 6-in. Borsig valve that was tested at Essex operated satisfactorily under emergency conditions.

Motor Control

There is hardly a piece of machinery in the power plant that is subjected to such extreme operating conditions as the motor-controlled valve:

a It is usually located in an out-of-the-way gallery and covered with coal dust, and in a temperature ranging between 150 and 165 deg. fahr. which necessitates special heatproof motor-coil insulation

b It is thrown directly across the line without the aid of starting resistance so that the full voltage is impressed upon the windings, and at the same moment the motor may be called upon to exert its maximum mechanical effort in unseating a tightly seated valve

c It must be small and compact, automatically lubricated, and entirely steamproof and waterproof

d Periods of inoperation range from a minimum of one week to, say, three months, during which time plant conditions may be such as to prevent its operation; and it is expected to function perfectly, even though it has not been tested over this extended period

e Steam from a leaky gland may be allowed to blow freely on the control unit for an indefinite period, and to withstand this it must be impregnated

f In case of piping rupture it is more than likely to be enveloped in condensed steam, and just at this time it will be called upon to exert its maximum mechanical effort to close the valve.

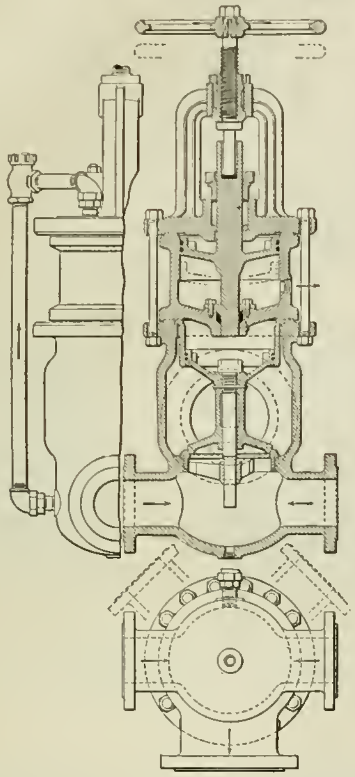

Fig. 3 Cross-Section of an Emergency Piston-Operated Steam Stop Valve

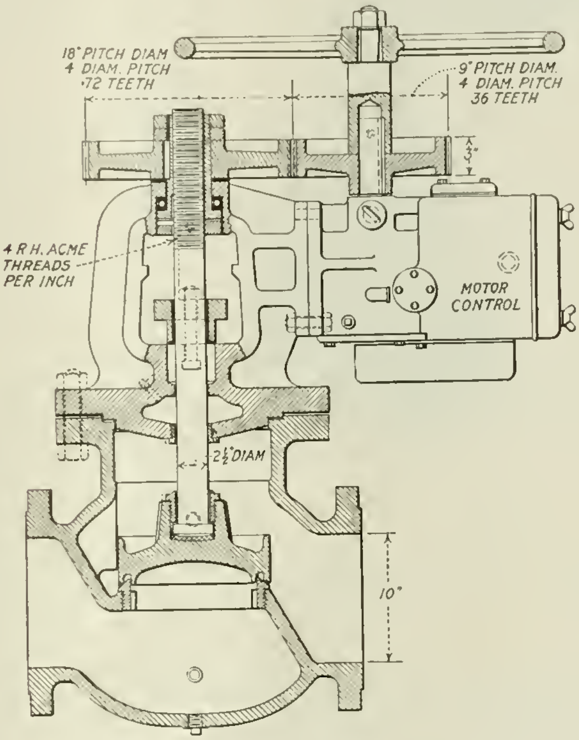

Fig. 4 Cross-Section of an Electrically Operated Globe Valve Provided with Ball Thrust Bearings

The duty on such equipment is extremely severe and without doubt necessitates much special construction. The motor must be of the totally enclosed type and provided with ball bearings of excessive diameter. It should be bolted directly to the reduction-gear casing, leaving no coupling or high-speed shafts and bearings exposed. It should be series wound with such characteristics that it will automatically slow down upon the application of load caused by the valve disk passing into the seat. This is the surest means of protection against cutting of the disk and seat rings.

The reduction gears should be of heat-treated steel, on account of their compactness and the excessive strain that may be applied and should be continually immersed in oil. Any oilless or self-lubricating type of bearing for either the motor or slow-speed shaft should be avoided on account of its inability to withstand excessive heat, long periods of rest, and the accumulation of dust in the bearing.

On account of the excessive drift of the motor armature and gears after tripping, a declutching device should be provided to enable the valve stem to be stopped automatically at a predetermined point without jamming. In the same casing should be provided a self-contained electrical limit which is capable of breaking the main motor current without arcing and so geared that operation of the valve by hand will not throw it out of adjustment.

The casing should be provided with one conduit opening arranged for making a steamproof joint between the internal connections and the line and all internal connections should be of asbestos-covered heatproof cable.

Control of the valves may be effected from either one point or from multiple points by the aid of a totally enclosed dustproof reversible drum switch capable of reversing the armature connections.

The stations should be provided with lamp indication showing the full open and closed positions of the valve at all times. Such a control switch should be provided with a lock, an emergency glass window, and hammer. For multipoint control an interlocking system should be provided so that the first operator to reach a valve will have full control even though other control stations are operated at the same time and in reverse directions.

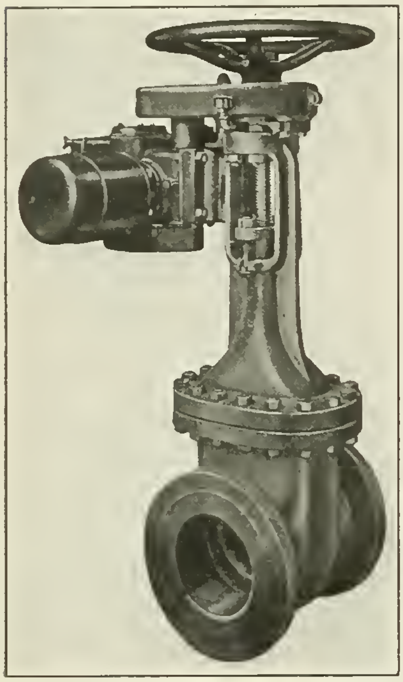

Fig. 5 Typical Electrically Operated Boiler-Lead Valve

In every case both poles of the electrical circuit should be interrupted when the switches are in the "off" position. Single-pole break is dangerous, as a ground may cause the valve to either open or close and produce very serious inconvenience.

Voltage. A valve control system should be connected to the most reliable source of current in the station, which is either the direct current exciter or switch control battery circuit, as it is equal in importance to any piece of auxiliary machinery. The voltage should not exceed 250, firstly because direct-current battery circuits of this voltage are standard, and secondly, because higher voltages would cause an unnecessary strain on the very closely packed windings. Valve motors are thrown directly across the line without resistance and encounter at the same moment their full mechanical strain due to a tightly seated valve.

Control-Station Location. Each valve should be provided with a local control station, mounted at some point from which opening and closing the valve may be observed. Preferably there should be two points of control for each valve, one in the boiler room close to the door leading into the turbine room, and the other at a safe point unlikely to be affected by steam flow. Where a centralized control board is adopted, the second point of control may be mounted in the turbine room, and for the closing of the turbine lead valves the control may be mounted on the turbine gage board.

Conduit and Cable. All conductors should be suitably protected by fuses having a capacity equal to the full-load starting current of the motor, and fuses rather than switches should be provided for disconnection. The cable should be chosen according to the location, and for the operation of high-pressure super-heated steam equipment, cable should have an asbestos heatproof covering.

It is a good plan to end the rigid conduit within 3 ft. or so of the control unit, and from that point use a flexible loop of Greenfield or similar duct. This will allow considerable vibration in the pipe line without affecting the cables, and will further enable the control unit to be freely moved.

Hand Operation. Handwheels should be provided in case of failure of current supply. No declutching device should be installed between the motor and valve which destroys the relative position of valve and motor mechanism. A properly designed and cared-for valve-operating system, especially in a power plant, need never fail, and in case of possible failure at a critical moment the valve may be closed by the handwheel, through the gears and motor, in almost as short a time as when the parts are disconnected. The great danger of a declutching device is that it is very apt to be left disconnected with no means of showing its position at the control station, and that it introduces a non-foolproof feature by providing a piece of mechanism that can be tampered with by any unauthorized person.

If such a device is insisted upon, it should be a self-contained part of the mechanism and operated externally by the aid of a wrench. Further, it must be so arranged that positive indication of its position must be noted on the indicating lights at the control station.

Periodic Tests. Every electrically operated valve should be opened and closed at least once a week, preferably under load conditions if possible, and an examination of the internal parts should be made at least once a month and all records of such tests and examinations kept on file.

The Author's Control System

The Dean control system of valve operation was designed exclusively for the operation of valves, and since it embodies all the

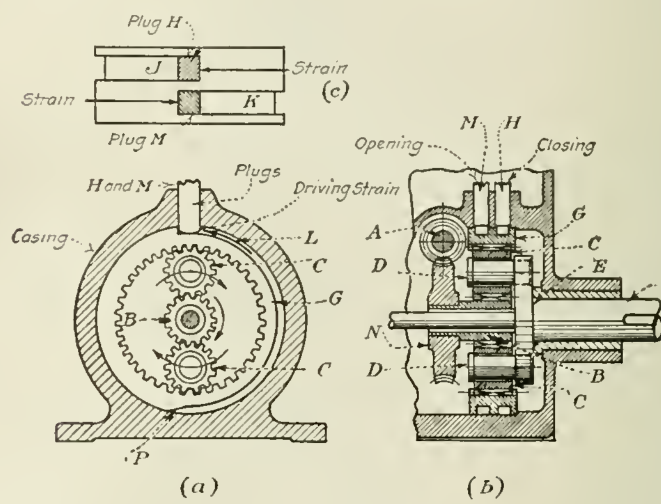

Fig. 6 Mechanism of One Type of the Author's Valve-Control Unit

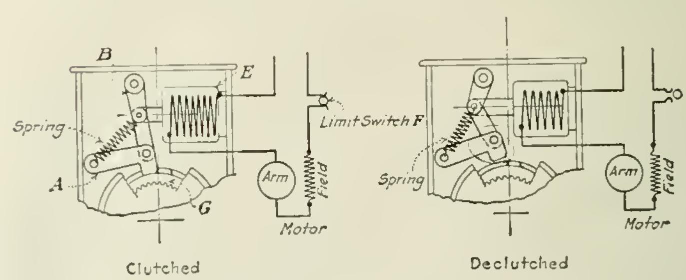

Fig. 7 Sketch Showing Principle of Operation of a Second Type of Valve-Control Unit

features that have been enumerated, only a brief description of its mechanical operation will be given.

The type E unit consists of a driving motor, reduction gears, and limit trip mechanism mounted in a single case. The feet of the unit are provided with four holding-bolt holes of standard dimensions for a given range of valves. Four standard units cover the complete line of valve sizes in use.

The motor is totally enclosed and steamproof, and possesses an extremely high torque. It is connected to a system of combination worm and planetary gearing for the necessary reduction in speed. The motor speed is normally 1600 r.p.m. and that of the slow-speed shaft 40 r.p.m., the gear reduction being 40 to 1.

The motor shaft is coupled to the worm shaft A (see Fig. 6) both running in ball bearings, and the worm wheel N is keyed to a sleeve forming the sun pinion B of a planetary gear. The planet pinions C revolve on large studs D forced into a flange E

forming part of the slow-speed driving shaft *F*, and these pinions mesh into the internal gear *G* forming the outer member of the planetary.

Fig. 6 (*a*) shows the assembly of the planetary gear, the external member or internal gear of which is marked *G*. The center or sun pinion *B* is caused to revolve by the motor, and this pinion turns the planetary pinions *C* and shaft *F* in the direction shown. The outer member or internal gear *G* is free to revolve on a machined surface in the casing, but is restrained from doing so by two plugs *M* and *H* which also pass through the casing in the manner shown.

Fig. 6 (*c*) shows another view of the outside surface of the internal gear *G*, and it will be seen that this surface is provided with two peripheral channels, one extending half-way around in one direction as shown at *J*, and the other in the opposite direction as at *K*. When both plugs *H* and *M* are in, or in the locked position, the internal gear *G* cannot move, therefore with the sun pinion being driven by the motor, the planetary pinions must turn on their own axes and travel around the internal gear, thus also moving the flange *E* and drive shaft *F*.

Referring again to Fig. 6 (*a*), let it be assumed that the valve is closing and the plug *H* is restraining the movement of the internal gear which tends to move in the direction indicated by the arrow *L*. At a predetermined moment when the valve is tightly closed, but not jammed, this plug is quickly withdrawn from the slot by a special cam movement, and since there is no friction now restraining the movement of the internal gear, it is of course free to revolve in the direction shown.

At the precise moment of withdrawing the plug the electrical circuit is interrupted by the limit switch and the drift of the motor coming to rest is taken by the internal gear revolving in its casing. Experiments and practice tend to show that the motor comes to rest after the internal gear has traveled about half a revolution. Should any further drift take place, the plug *M* is automatically moved upward by the moving tapered stop *P* in the groove, which operation does not open the electrical limit.

It will be noted that the plug *M* is still in the other slot. During the opening of the valve the motor will of course be reversed, and the internal gear will have to revolve in the opposite direction before the plug *M* comes in contact with the stop. This provides a hammer blow which is sometimes necessary to open a tightly seated valve, but it is by no means essential as the motor has sufficient torque with which to operate the valve under all conditions.

It is very easily seen that the moment one of the plugs is withdrawn, the slow-speed drive shaft stops instantly and that it can only stop at exactly the same point during every operation, quite irrespective of load or friction. Thus the valve gate is never jammed.

The valve gate is made to seat tightly, under power, and to a predetermined point, drift and overtravel being disregarded as a means of seating the gate.

Tachometer readings show that at the moment after tripping, the motor armature speeds up considerably before the electrical limit contact is broken, which indicates that the load is released prior to the interruption of the circuit, in this way eliminating arcing.

The gearing for speed reduction is encased in a cast-iron housing partly filled with oil, so that the gears are always well lubricated. The limit mechanism is contained in a separate part of the housing and provided with a removable cover.

The type M or magnetically operated improved Dean system as shown in Fig. 7 (*a*), is very similar to the type E design with the exception of an improved limit and method of releasing the restraining plugs. In place of the plugs *H* and *M* as shown in Fig. 6 (*b*), a restraining pawl *A* is provided which is held in the operating position by an energized magnet *E* connected in the main electrical circuit. At the moment the electrical limit switch trips at the end of travel the spring-operated toggle *B* is broken and the restraining pawl *A* instantly releases, allowing the internal gear *G* to freely revolve and take the complete drift of the motor armature. A very noteworthy feature in this design is that the handwheel is always free to operate without the necessity of employing a declutching device.

Discussion

N. E. Funk[1] said that the non-return valve, if motor-operated, provided the simplest scheme of boiler control. However, the practice of placing gate stop valves on the boiler header in addition to the non-return valve on the boiler was almost universal, so that it was better to operate the valve which was most readily controlled when there was any choice.

Since very definite tests had been made on gate valves showing their characteristics in so far as shutting off high-velocity steam was concerned, and since this information was not available on non-return valves, apparently the best engineering judgment would be to operate the gate valves electrically and use them to cut off the boilers in event of trouble.

There was a possibility that considerable trouble would be experienced in shutting a non-return valve against extremely high steam velocities experienced in event of the break of a header. There was considerable unbalance in this type of valve and it was necessary to shut the disk directly against the stream flow of the discharging steam. Mr. Funk believed that any attempt to use the non-return valve in this manner not only complicated the valve, with a tendency to make it less likely to function when it should act as a non-return valve, but also would mean redesigning practically all of them so that they would withstand the tremendous forces encountered when shutting them against a break.

Experience in closing a standard 250-lb. non-return valve against a 400-lb. hydrostatic test on the boiler had shown how difficult it was to make such a valve tight, it being necessary for two men with a long wrench to pull up on the hand wheel to put a heavy strain on the disk to keep the edges from lifting under this pressure and causing the valve to leak.

Trouble of course might be experienced in shutting gate valves by having the wedge plow up the seat and turn up enough metal ahead of it to prevent the gate from closing. The tests made at the Essex plant, however, seemed to indicate that not much fear of this need be experienced.

Until very recently large steam valves had been operated electrically more as a matter of convenience and labor saving than with the idea of shutting off the steam in event of a steam-line break. The old types of controls, however, would not close a valve against any unusually high steam velocity due to insufficient power in their operating mechanisms.

As to steam-pipe sectionalization, Mr. Funk stated that he had heard some very good engineers speak more or less disparagingly of such procedure, indicating that they believed that piping should be so designed that it would be impossible for a break to occur. But even if everything was tested considerably above its working pressure, there was a possibility of rupture from outside causes or from flaws which could not be detected in this manner. In addition, with the industry thinking of higher pressures and temperatures at which there was uncertainity as to what would happen to the metal, the necessity of sectionalizing was even greater.

His company believed thoroughly in remote control of steam valves, and in their new designs were not only arranging to shut off each boiler from a remote point, but also to sectionalize the steam-pipe headers. The remote-control point was located outside of the turbine and boiler rooms so that no matter where a break occured the damaged section might be isolated without a serious or lengthy interruption of operation.

W. S. Morrison[2] said that the New York Edison Co., operating at only 200 lb. pressure, had never experienced any difficulty in valve closing, but to forestall any such troubles as those described in the paper they had provided controls on their 18-in. header valves. When they came to consider the question of higher pressures, however, the subject would be analyzed a great deal closer.

Alfred Iddles[3] said that it seemed to be the general practice to consider the non-return valve purely as a check valve, and that in his opinion it should be confined to this use for the present. Later it might be possible to develop a device that would function successfully as a combined shut-off and non-return valve.

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[2] Asst. Mech. Engr. N. Y. Edison Co., New York, N. Y. Mem. A.S.M.E.

[3] Mech. Engr., Day and Zimmerman, Philadelphia, Pa. Mem. A.S.M.E.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

The Gas Turbine in Theory and Practice

A SERIES of articles discussing the subject broadly. The author considers the problem of gas-turbine development a difficult one but not impossible of accomplishment. It is primarily, in his opinion, a matter of engineering design and selection or development of suitable engineering materials. As regards the field of the gas turbine, he believes that while it will not displace in many cases the present internal-combustion motor, it will, under certain conditions, prove a formidable competitor of the steam turbine. It has, however, a long road to travel before this will really become of serious commercial importance.

As regards the competition between the gas or heavy-oil engine and the gas turbine, the former though economical when it does not exceed a certain power output, becomes unwieldy in very large sizes. The real scope for the internal-combustion turbine will be found in certain cases where, in competition with steam plants, the elimination of the boiler and condensing installations offers peculiar advantages, while in other, such as the utilization of blast-furnace gases, the fact that it can be made to develop large powers on comparatively small dimensions may, even in spite of possibly inferior thermal efficiency, render it a suitable alternative to the large gas engine. Until, however, some well-thought-out design is actually constructed and tested, engineers must rest content with estimates of efficiency instead of proofs, and it remains to be seen whether they are of a sufficiently attractive nature to justify embarkation on the development of a new type of prime mover. Without experimental verification, much further progress in the design of the gas turbine cannot possibly be made.

The main difficulty encountered by designers of gas turbines lies in the usual severe temperature conditions. In the constant-pressure internal-combustion turbine, the application of heat at its maximum is constant; both in it and in the constant-volume type the blading is subject to a constant impinging temperature, although one of reduced intensity, but in both cases the function of the material is to withstand the heat and, as far as possible, not to transmit any of it. It will immediately be realized, therefore, what considerable differences and difficulties are involved in the use of internal-combustion products, whether expanding in a cylinder against a piston or impinging upon a turbine wheel through a nozzle, for the maximum reduction in initial temperature that can efficiently be used in the latter case is only in the region of 1000 deg. fahr., and therefore the temperatures in furnace, combustion chamber, or explosion chamber, and that on the blading can only be separated by about this amount. This very high initial temperature of the working fluid at first involved very considerable mechanical difficulties, even in the intermittent working of the reciprocating oil engine. It has hitherto almost entirely frustrated the solution of the gas-turbine problem, and nearly all, if not all, the serious difficulties encountered arise from this element—the initial temperature. The constructional troubles likely to be created from this cause react on the entire proportions of the design, and in order to obviate them recourse must eventually be had to improving the heat-resisting properties of metal. At present it is necessary either to restrict the initial temperature to such a point that, with the nozzle drop, the impinging temperature—probably the cardinal point in all gas-turbine design— does not cause deterioration of the blading, or else to accept some form of intermittent working, either of which will reduce the amount of positive work obtainable from the cycle or involve a more elaborate machine. The nature of the internal-combustion cycle—to be referred to later at length—completes the chain of difficulties, because, if the turbine operates on the constant-pressure cycle, the proportion of negative work to the available positive then becomes unduly large; while if it operates on the constant-volume cycle, the positive work obtainable can only be developed in a multi-chamber machine which, compared with other forms of prime mover, is unduly large and complicated. Moreover, the real point at issue must always be borne in mind; there is no question at all of evolving an internal-combustion turbine which shall be saliently superior to the present oil engine, just as the steam turbine proved to be to the reciprocating engine; economically this is probably impossible with a non-condensable gas. The real question is whether, in spite of these limitations, and the difficulties which are liable to arise if they are exceeded to any extent, a gas turbine can be produced which will compete with the steam engine and its accessory plant.

Of all the fragmentary work which has already been done on the gas turbine very few designs and even fewer test results have actually been made public. It would appear, however, that efficiencies equal to or even exceeding the best oil-engine practice are probably obtainable in theory, though not within the same cycle limits. They are not in sight today and are unlikely to be for some years, mainly owing to the lack of material suitable for withstanding the very high temperatures which such efficiencies demand.

The original article gives construction data and results of trials of a number of internal-combustion turbines. This part is not suitable for abstracting.

Of the many various types of gas turbine which have been constructed, the majority were designed to work on the constant-pressure cycle; but of those for which any detailed information has been published, three out of the seven were explosion turbines working on a constant-volume cycle, one was an exhaust turbine, and the remaining three, while operating on the constant-pressure superatmospheric cycle, were all mixed-fluid turbines. That is, besides the air and the fuel, steam or water injection was used to reduce the temperature of the mixture. Two of these constant-pressure, mixed-fluid turbines were also tested with air only. No published results are available beyond these air tests for a pure constant-pressure single-fluid machine, nor for any gas turbine working on a subatmospheric cycle, though the latter would probably give results very much superior to any other type. Before going any further into the question, it is necessary to explore the possible efficiencies obtainable when operating the turbine form of engine on an internal-combustion cycle, and the constant-pressure method will be investigated first.

In all heat engines the continuous output of work is effected by some from of mechanism which utilizes the pressure difference in a working substance created by the heat energy supplied. Whichever cycle is adopted, however, the internal-combustion turbine, as is the case in all practical heat engines, consists of the following essential parts:

1 A furnace or combustion chamber in which heat is supplied to the working fluid.

2 A heat sump or cooler into which the working fluid expands after leaving the combustion chamber.

3 Between these, a mechanism which will absorb the available energy of expansion in the fluid as it flows from 1 to 2 and reproduce it in the form of positive work, and

4 A mechanism which may either (*a*) supply the working fluid to the combustion chamber, (*b*) withdraw it from the cooler, or (*c*) combine both functions.

The work for these may be supplied either by the excess positive work or by other means, but in any case forms the negative work of the cycle. Owing to the fact that for the heat flow from furnace to cooler—which in the case of internal-combustion engines using

non-condensable gases must eventually be the atmosphere—and because this rejection usually takes place at a pressure somewhat greater than that of the atmosphere, in the constant-pressure cycle air must be supplied to the furnace under pressure, whereas the constant-volume cycle can, if necessary, be worked without precompression, although a certain small amount is advisable in practice. In lieu, however, of using a purely superatmospheric cycle, either an entirely subatmospheric cycle can be adopted, an exhauster taking the place of the compressor, or a combination of the two may be adopted. Precompression has hitherto always been adopted, the subatmospheric cycle not having been employed, and with the exception of Holzwarth, who uses a very small degree of exhaustion, the exhaust pressure has hitherto been above atmosphere. It was stated above that the constructional difficulties all arose through the element of temperature. The very real difficulty in achieving an efficient design of internal-combustion turbine, which would render it *facile princeps* among prime movers, lies in this matter of compression or exhaustion—that is, in the negative work of the cycle.

It should be clearly emphasized at this stage of the thesis that the broad principles upon which heat energy can be supplied, absorbed, and rejected in their various proportions are perfectly well known, and that no design which fails to comply with them can possible succeed. This is the reason why a good working solution of the internal-combustion-turbine problem depends in no way on some fortuitous or radically novel design on the part of some lucky inventor.

Owing to the initial temperature difficulty, the reaction turbine is unsuitable for the internal-combustion cycle, though it may become feasible eventually for the exhaust and in the case of certain forms of subatmospheric working, but only if very large volumes are involved. Our choice is therefore restricted to either the single-wheel impulse turbine or to a velocity-compounded turbine with two, or possibly three, rows of moving blades, though it is very doubtful if the efficiency of the latter is even nearly adequate. From the cycle limits and the analysis of the working fluid, it is possible to calculate the maximum value of the available energy, and the turbine efficiency is the ratio between the useful work developed in the turbine shaft and the energy available for expansion. Two transformations of energy take place in the turbine: first, from thermal to kinetic energy; secondly, from kinetic energy to useful work. The first loss which occurs lies in the radiation from the combustion chamber, which reduces the amount of energy available for conversion into kinetic work; the second consists in the friction and eddy losses in the nozzle. From this point the author proceeds to a discussion of the various losses.

As regards the stage efficiency of the turbine itself, the author bases his opinion on curves of stage efficiency for various ratios of blade speed to steam speed for different angles of wheel for which data have been published by Lasche and Baumann. From this it would appear that within very narrow limits the respective stage efficiencies do not exceed 0.8 and 0.68. All things considered, the author comes to the conclusion that for gas-turbine work the two-row wheel is practically the only one suitable.

It would therefore appear that the successful operation of a gas-turbine, apart from questions of mechanical construction, depends primarily on: (1) The ratio of positive to negative work in the cycle employed, and (2) the efficiency of compression and expansion, and for the constant-pressure superatmospheric-cycle single-fluid machine it was shown that with a two-row velocity-compounded turbine of 65 per cent efficiency, the ideal brake efficiency, even with an initial pressure of 500 lb. per sq. in. pressure, would not exceed 19.6 if the compression were adiabatic and the compressor had an efficiency of 90 per cent, or 23.2 if the compression were isothermal and the efficiency reached 70 per cent. These brake efficiencies are capable of considerable improvement on the air cycle used, but when dealing with the real working fluid the absolute thermal efficiency is adversely affected by the variation in the specific heat of the substance.

Compared with the internal-combustion piston engine, the gas turbine can never enjoy the vast advantages over the reciprocating type of mechanism which the steam turbine possesses. The same brake thermal efficiency may be obtained by working comparatively inefficiently on a cycle of high absolute efficiency just as well as by working more efficiently on a cycle of lower absolute efficiency. This is precisely what occurs in the case of the steam turbine and the piston engine. With steam, however, enormous expansion ratios are readily obtainable, in fact, a volumetric expansion of 750 to 1 is not out of the question, and the turbine mechanism lends itself very readily indeed to the utilization of small pressure differences and the "toe" of the P-V diagram. It can also utilize much higher superheat than can the engine, for there are no surfaces in contact, as well as vacuums which are entirely beyond the range of constructional possibilities where piston and valve mechanism are involved. Increased thermal and mechanical losses with reciprocating mechanism follow any attempt to go far in the direction of utilizing the energy of expansion at pressures below about 2 lb. abs., though there is still useful energy remaining in the steam. The result is that this engine is restricted to a cycle

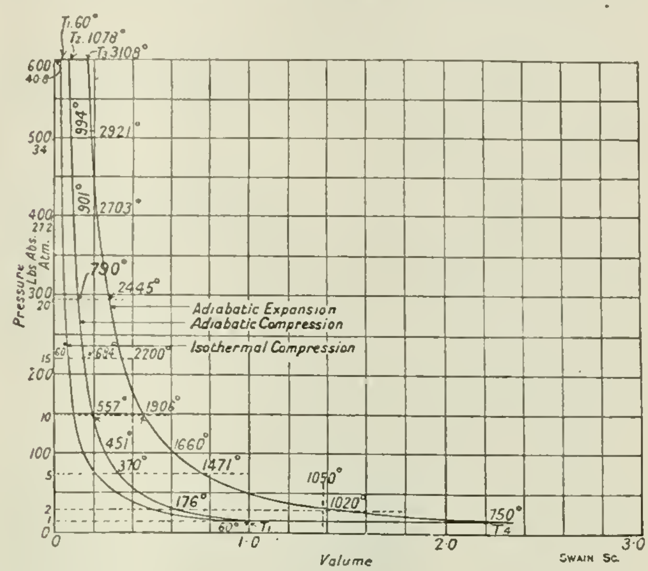

Fig. 1 Pressure-Volume Diagrams for Various Cycles

of much lower efficiency In the internal-combustion piston engine, as shown in Fig. 1, the "toe" of the diagram with atmospheric exhaust only forms a small proportion of the available work, this fraction becoming smaller as the initial pressure increases. But with the products of internal combustion, which are non-condensable gases, the advantages of the turbine over the piston engine, in that it can utilize the "toe" of the diagram, very largely vanish, because the expansion ratio is greatly curtailed by the fact that the gas does not change state, and though use can be made of subatmospheric working, the limits of the internal-combustion P-V diagram cannot be extended in the same manner as they are with steam owing to the condensation which the latter undergoes. We are, in the internal-combustion turbine, as with steam, employing a mechanism of lower intrinsic efficiency with which to extract the available kinetic energy, but whereas in the latter the limits between which we can readily work are so much greater, and consequently so much more energy per pound of working fluid is available, in the former the range of expansion available hardly differs at all in the two cases, and pressure compression ratios in both exceeding 15 offer hardly any advantages with the materials at present at our disposal, as higher compressions involve initial temperatures which become increasingly difficult to handle. The efficiency of a non-condensing steam turbine is notoriously low, and between initial and atmospheric exhaust pressures the piston engine is much superior—is even superior down to, perhaps, 26 in. vacuum. The same applies with internal-combustion gases, and no little misapprehension has often been caused by lack of appreciation of the fact that the turbine per se is inherently less efficient than the reciprocating engine except in the utilization of the subatmospheric range, but that it derives its vastly superior brake thermal efficiency from the fact that it can operate on a cycle of far higher absolute thermal efficiency, and *not* from the fact that its mechanical efficiency or efficiency of energy conversion is better, because it is not so except at very low pressures.

With the limit of velocity-compounded-turbine efficiency on the

low side of 70 per cent there are two directions in which improvement in the efficiency in internal-combustion-turbine installations can be made, viz.: (1) By increasing the air-compressor efficiency, and (2) by an increase in the ratio of positive to negative work in the cycle. The former improves the thermodynamic efficiency of the combination, and therefore the brake thermal efficiency for a given cycle. *The Engineer*, vol. 135, nos. 3514, 3515, 3516, 3517, May 4, 11, 18 and 25, 1923, pp. 466-468, 490-491, 515-517, and 557-559, 7 fig., 12 tables.

Short Abstracts of the Month

AIRCRAFT ENGINEERING

A New British Light-Weight Airplane

The Gnosspelius Light Plane. General description of the airplane designed by Maj. O. T. Gnosspelius and recently tested at the Lympne aerodrome.

The design of the plane is based on aerodynamic tests made with the pendulum apparatus which was developed at the works of Short Brothers. On this pendulum the models are mounted with the wings parallel to the pendulum arm, and the tests are carried out by raising the pendulum to a horizontal position, releasing it from there and noting how far it swings up on the other side of the dead center. This gives an indication of the resistance of the model, while the lateral deflection of the pendulum at its lowest position gives an indication of the lift.

On this pendulum Major Gnosspelius has tested a large number of models, and he has discovered several very interesting, and to some extent inexplicable, things. First of all he tested certain wing sections of which data were already available. He found that reasonably good agreement was obtained. He then tested other wing sections, as, for instance, the R.A.F. 19, which was found by model tests at the National Physical Laboratory to give a very high lift. On the pendulum this high lift was not attained. Now the curious fact about this test is that when tested on the full scale R.A.F. 19 does not give the high lift which wind-tunnel tests on models indicated. The logical conclusion seems to be that the pendulum, in certain circumstances, is in better agreement with full-scale work than is the wind tunnel. A good deal more evidence is necessary before one can definitely say that this is so, but several experiments seem to point that way. If this should prove to be so, the fact may considerably alter present views on aerodynamics, and it even seems possible that the phenomenon commonly known as "scale effect" does not exist, and that the differences between model and full-scale results, as indicated by wind-tunnel tests, may be due to other causes, possibly to the effect of the walls of the wind tunnel.

The Gnosspelius light plane has considerable resemblance to a bird in so far as the shape of the wings, body and tail are concerned. The body, which is of circular cross-section, comes to a point in the nose, and this point is not on the center line but is slightly bent down much as is the head of a bird during flight. The tail plane is long in relation to its span and is of triangular plan form. The ailerons are of considerable size, each being over 12 ft. long and of high aspect ratio.

The wing section employed is of fairly deep camber, although not of great thickness. One result of this is that it would have been almost impossible to obtain sufficient torsional stiffness with the usual two-spar construction. Consequently Major Gnosspelius decided to employ four spars, and so to design his ribs that any deflection of any one spar should be transmitted to the other three. The spars themselves are of the box type, with spruce flanges and three-ply walls. The ribs are of lattice construction, with double flange strips, in between which are passed the ends of the lattice bars, tacked and glued in place. To be quite accurate, it should, perhaps, be said that the ribs are N-girders rather than lattices, as the compression members are vertical.

The plane weighs about 530 lb., which figure includes gasoline or about two hours' flight, and the minimum horsepower required or horizontal flight is in the neighborhood of 3 b.hp.

The machine is fitted with specially light glider instruments such as an air-speed indicator reading from 10 to 80 m.p.h., a revolution indicator, an aneroid, and oil-pressure gages.

In tests during the first flight a height of about 1500 ft. was reached, the machine climbing strongly. The duration of this flight was about 15 min. In the next flight a height of 2500 ft. was reached and the machine remained in the air for approximately half an hour. The maximum horizontal speed attained as shown by the air-speed indicator was about 65 m.p.h. (*Flight*, vol. 15, no. 753/22, May 31, 1923, pp. 292–295 and 291, 8 figs., *d*)

AIR MACHINERY

Explosions in Air Compressors

Explosions in Air Compressors, J. A. Vaughan. Discussion based on official inquiries into sixteen explosions occurring in the pipes of passages through which the gas passed. The author comes to the following conclusions:

a Carbonaceous deposit is the seat of the trouble.

b Leaks in the final stage of compression or discharge are dangerous.

c The most likely time for firing or explosion is when the compressor is unloading.

d One or two fusible plugs do not provide an adequate safeguard against firing, explosion, or the delivery of dangerous air to the mine workings.

e The system of temperature gaging and record requires alteration.

The term "carbonaceous deposit" is used to denote the deposit which is left in the intercooler system, the valve chests, or the discharge passages owing to the cooling and the baffling influences to which the moving compressed air is subjected.

The proximate analyses of the deposits show that the substance, besides being a good gas reservoir, is of a nature liable to spontaneous combustion, while it is probable that the presence of metals in a finely divided state accelerates the oxidizing process, these metals being maintained in an unoxidized condition owing to a protecting film of oil.

There is little doubt that, as is the case with coal, the rate of absorption of oxygen rises with the temperature, so that, seeing that the temperature of the carbonaceous mass is necessarily increased as the oxidation proceeds, the rate of absorption will increase by a sort of compound-interest law, in the absence of any cooling effects.

The discharge pipes and receivers are unlagged and free to radiate heat, while at full load the stream of compressed air (at, say, 300 deg. fahr.) must assist in retarding any tendency of the deposit to heat up to a dangerous degree, unless the deposit is situated in mass, out of the flow, as may be the case in the bottom ends of intercoolers.

As regards the leaky discharge as a source of danger, the author shows by a series of indicator cards the effect of a leak, which, in this case, was intentionally created in the valves or piston of either the first or second stage of a 1440-cu-ft. air compressor. The inspection of the diagrams shows material alterations from normal conditions. Among other things, the fact that in a two-stage compressor leakage in the high-pressure discharge valves or in the piston will always raise the first-stage discharge and intercooler pressures. The temperature of the compressed air in this position will always necessarily be higher.

At full load the effect of the high-pressure discharge-valve leak is to put more work on to the low-pressure side. In this cylinder, with its inlet a little delayed due to the clearance air being of a higher pressure, a full charge of air at atmospheric pressure is compressed to a pressure higher than normal, the actual height reached depending on the size of the leak, which determines the point of the high-pressure stroke at which the inlet valve will open. The capacity of an intercooler of usual proportions will not be sufficient to prevent a rise of temperature on this account. If the leak were sufficiently large the high-pressure piston would merely float in air at receiver pressure, while the whole of the compression would be accomplished in the first-stage cylinder.

In addition, the author presents the curve giving data of tests with a broken valve plate in the second-stage discharge, from which it would appear that:

a Heating undoubtedly does take place if a high-pressure discharge valve leaks.

b The smaller the load, the greater the heating effect under this system of governing.

c The higher the pressure, the greater the heating effect.

There are two causes, interlinked, why leaky discharge valves produce rise of temperature in the receiver air (meaning by this term the compressed air that is in the discharge pipe or receiver—outside the high-pressure cylinder):

a The rate of compression in the low-pressure cylinder is increased, as more work is performed by this cylinder and a higher delivery pressure reached. Therefore the high-pressure intake is at a higher pressure and temperature, and consequently the high-pressure delivery and the receiver air are higher in temperature.

b The air that leaks back into the high-pressure cylinder does not fall appreciably in temperature on reëxpanding, and is by reason of its recompression delivered back to the receiver at an increased temperature.

As regards the danger at the time of unloading, the author advances the point that this time appears to be the most suitable for the proper explosive mixtures to be formed. Further, the dangerous gases being formed at the compressor end of the line should be capable of detection. An alarm device which would call the attention of the engineer to danger in that carbon monoxide or methane were being generated, should prove effective in preventing gassing or explosion. (*The Journal of the South African Institution of Engineers,* vol. 21, no. 9, April, 1923, pp. 171–176, 7 figs., *pA*)

ENGINEERING MATERIALS

Tentative Specification for Gray-Iron Castings. Text of the specifications prepared for submission to the Manchester Conference of the Institution of British Foundrymen in June, 1923.

All gray castings are divided into two classes: important castings, in which test bars shall be cast on when possible; and other castings, in which the bar may be cast separately at the option of the foundryman.

The thicknesses of any casting shall determine the size of the test bar required, namely:

Bar 0.875 in. diam. cast 15 in. long, for all castings where no main cross-section of the metal exceeds $^3/_4$ in. in thickness.

Bar 1.2 in. diam. cast 21 in. long, for all castings where no main cross-section of the metal exceeds 2 in. in thickness.

Bar 2.2 in. diam. cast 21 in. long, for all castings where no main cross-section of the metal is less than 2 in. in thickness.

The specification gives requirements for the transverse test and the tensile test, and provides that where physical tests are specified the amount of any chemical element other than phosphorus shall not be specified, and for phosphorus only its maximum percentage. (*The Foundry Trade Journal*, vol. 27, no. 354, May 31, 1923, p. 449, *p*)

Pearlitic Cast Iron. Pearlitic cast iron is a cast iron having a microstructure consisting mainly of pearlite with deposited graphite. The properties claimed for it are said to be:

1 High transverse and tensile strengths and toughness

2 High resistance to impact stresses

3 Moderate hardness when properly treated

4 Only a slight tendency to the formation of "pipes," and hence the possibility of making complicated castings

5 Great resistance to sliding friction (abrasion)

6 Fine and dense structure, the structure being unaffected by temperature changes.

The process of producing pearlitic cast iron consists essentially in the combination of two media, in the variation of the furnace charge, and in the correct heat treatment of the molds. Correct mixing is intended to give as little stimulus as possible to the formation of graphite. The materials used are carbon, silicon, and low-phosphorus pig iron. High sulphur content does not appear to be detrimental.

When cooled in the ordinary way, an iron of this kind would solidify "white." In order to preserve the desired pearlite-graphite structure a slow rate of cooling is necessary, this being obtained by preheating the mold. The degree of preheating depends of course on the wall thickness of each particular casting.

Theoretically speaking, it would be possible to get, from one and the same charge, and by suitable heat treatment of the mold, every desired cross-sectional area with the same final product (pearlite-graphite structure) when once the rates of cooling for the different cross-sectional areas had been determined. In practice, various cross-sectional areas are grouped together and a special burden or charge selected for each group, assuming the same amount of preheating of the mold. The possibilities of pearlitic cast iron have been discussed by Professor Bauer in a recent issue of *Stahl und Eisen.* The present writer has carried out some tests with the view to determining whether the claims for this new type of cast iron are justified and gives the results in the original article. From these it would appear that pearlitic cast iron has superior strength properties as compared with other kinds of cast iron tested. It would further appear that the casting made by the pearlitic cast-iron process must be practically free from stresses owing to its slower and more uniform cooling, whereas the ordinary types of cast iron show considerable strains due to casting. (*The Foundry Trade Journal*, vol. 27, no 355, June 7, 1923, pp. 454–456, 5 figs., *dp*)

FUELS AND FIRING

The Clyde System of Oil-Fuel Burning

The Clyde Oil-Fuel Burning System. Description of the equipment fitted on the *Fezara*, a geared-turbine steamship of the Khedivial Mail Line.

The outstanding features of the Clyde oil-fuel burning system are a compact and novel design of heater and pump unit, a simple

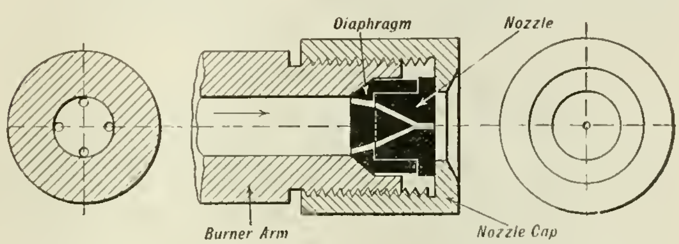

Fig. 1 Arrangement of Atomizer

oil-spraying device, and a special arrangement of furnace front, which, with suitable modification, may be fitted to any type of boiler.

In this system the fuel is drawn from the storage or settling tanks and suction strainer by a pump, which delivers it to a heater in which its temperature and corresponding viscosity are raised to the point necessary for its complete atomization under pressure in the burner, through which it is injected into the furnace in the form of a finely atomized conical spray.

As regards the heater, the flow of the oil being in series through the tubes, the danger of silting up is obviated, for the scouring action set up sweeps the tube spaces clear and prevents any deposit taking place. But, should one tube give out, only a small part of the whole heating surface is rendered inoperative. The main heater body is made of cast iron, and has within it a series of bored holes which are interconnected at their ends by means of machined passages. The arrangement of these passages compels the oil to travel in a sinuous path throughout the entire length of the heater.

The atomizer used with the Clyde pressure-jet system is shown by Fig. 1. The patented spraying nozzle is carried on the lower extremity of an L-shaped arm which is clamped by a quick-release attachment to a fixed bracket on the furnace door. Both the diaphragms and nozzles have been designed for high efficiency. They impart to the oil projected into the furnace the centrifugal force necessary to break it up into a minutely atomized conical spray, in which condition it is in a position to combine intimately with the air required for combustion. The atomizing effect is produced by a series of four oblique holes converging toward a conical projection, and a feature of the design of this part is that the conical projection is completely shrouded, thus protecting the point from injury.

The spraying nozzles are so proportioned as to be capable of

completely atomizing the oil at pressures of 25 lb. per sq. in. and upward. The weight of the oil dealt with and the output of the burner may be varied through a wide range by increasing or decreasing the pressure. When working in conjunction with the air director, the contour of the flame produced may be kept constant throughout the pressure range for the particular size of nozzle which is being used. Should it become necessary to work at pressures either above or below the normal limit, it is only necessary to substitute another size of nozzle corresponding to the requirements of the new pressure. Only the nozzle need be replaced, and the diaphragm remains the same throughout all pressure ranges.

The furnace fronts are described in the original article. As regards the starting-up gear, which is an important element when no steam is available, a special steam boiler fired by a Clyde kerosene-vapor burner is employed, the steam generated in this boiler being used to drive one of the pumping and heating plants.

The original article gives data of the results obtained with the oil-fuel system described and also the steam and air systems which may be used in place of the pressure-jet system.

The Clyde steam-jet system of oil burning is not quite as economical as the pressure-jet system, but is cheaper in first cost. The low-pressure air system is especially applicable to small boilers, galley ranges, central heating, and general furnace work, the oil being atomized by air at a pressure varying from 8 in. to 18 in. water gage. The Clyde high-pressure air burners may be used in cases where intense local heat is required. None of these systems is described in any detail. (*The Engineer*, vol. 135, no. 3519, June 8, 1923, pp. 611–614, 15 figs., *d*)

INTERNAL-COMBUSTION ENGINEERING (See Measuring Apparatus)

MACHINE PARTS AND DESIGN

Avoiding Shock on Intermittent Machine Work

Avoiding Shock on Intermittent Machine Work, Fred Horner. Discussion of methods of overcoming the jerky action when tools are cutting ridges or passing over slots and gaps, and also for preventing backlash in gears.

After describing some of the cruder methods the author mentions types of electric drive which provide control by tappets appropriately situated at the table edge by which the motor speed is increased while the tool is traveling over the empty spaces, and brought to normal cutting speed just before encountering the metal again.

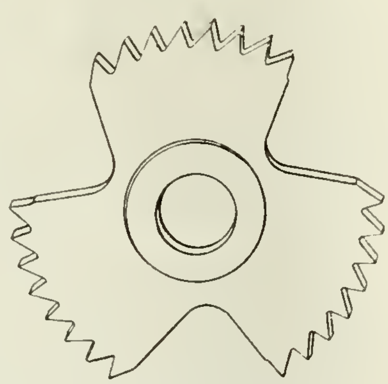

Fig. 2 Relieved Slitting Saw

The same principle is now being applied to the operation of some milling machines, feed increases being arranged to jump the work gaps at high speed.

The general object of such tools is to provide a relief from the strenuous continual action of normal tools, either in the way of dividing the chips into smaller portions, or of that idea combined with greater facility for chip escape. The principle embodied means omission of a succession of similarly shaped cutting edges, and their staggering or modification of lateral position, or the alteration of alternate teeth in such a way that successive chips differ.

The commonest model on the latter plan is the well-known stepped cutter used for gear cutting, which has nicked teeth with staggered grooves, and the cutter with alternate plain and waved teeth. A good many milling or slitting saws and the larger saws used on the regular cold-sawing machines are built with teeth having interrupted action, such as every other tooth a vee, splitting the square or round-nosed cut of the normal teeth. Or alternate teeth are beveled opposite ways, to throw the chips out freely. A somewhat similar incident occurs with the alternate-tooth mills now utilized for cutting deep grooves, the teeth standing to the right and left so that ample space for cutting and coolant is left in front of each tooth.

A novel principle has also been applied to slitting saws (Fig. 2) giving relief from the continuous cut all around and letting coolant get in and chips come out with greater ease. This scavenging action of the open spaces enables deep slots to be rapidly cut without fear of saw breakage. (*Canadian Machinery*, vol. 59, no. 22, May 31, 1923, pp. 17 and 24, 2 figs., *dt*)

Nomenclature of Power-Press Parts. The original article gives two drawings of a power press in which each part is numbered, together with a list of the names for the various parts. The availability of such a list is desirable as various terms are used to identify the same style of press; as, for example, "straight column," "straight-sided," and "straight-sided pillar." Even the machine itself is sometimes called a power press and some times a punch press; in the latter case it may be confused with the machine for punching holes in plates.

The nomenclature reproduced in the article is taken from a catalog issued by the Toledo Machine & Tool Co., Toledo, Ohio. (*Machinery* (N. Y.), vol. 29, no. 10. June, 1923, pp. 813, *p*)

MACHINE TOOLS

A Novel Combination Bench Tool

The Walker Mechanic. Description of a tool which aims at combining the features of a lathe, a drilling machine, and a vise.

The base of the machine comprises a casting which has more

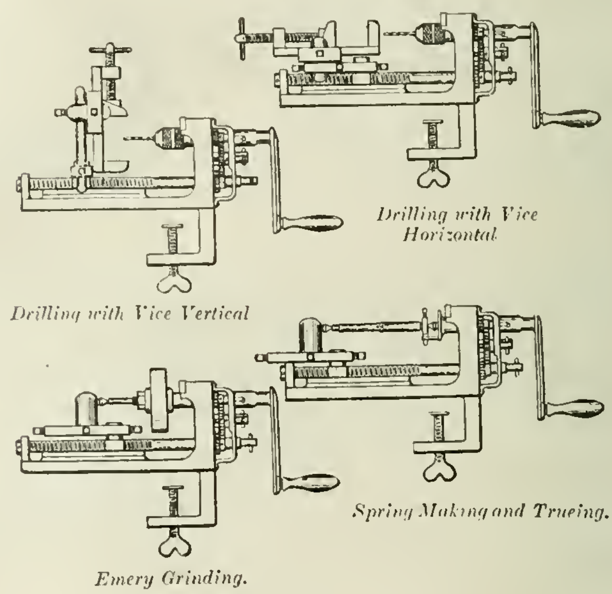

Fig. 3 The Walker Mechanic

or less the form of the front jaw of a parallel-jawed vise. This part, which is clamped on to the bench, is equipped with two short spindles and a long screw that are all geared together. The driving-crank handle can be fixed on any of the three spindles, so that a corresponding number of speeds can be obtained.

The illustrations show how, by means of some comparatively simple adapters, the machine can be employed in several different directions, while a substantial back jaw that is provided can be used in combination with the base and screw to form a powerful vise. The back jaw, incidentally, has a fair-sized anvil face and beak. (*The Practical Engineer*, vol. 67, no. 1894, June 14, 1923, p. 335, 1 fig., *d*)

MARINE ENGINEERING (See Fuels and Firing)

MEASURING APPARATUS

Positive Measurement of Fuel Oil on Motorships. Description of the Bassler meter, which integrates the flow through oil lines with compensation for temperature.

The meter may be calibrated either in "constant-weight gallons"

or in "constant-volume gallons" and in both cases it is, within practical bounds, unaffected by rates of flow, line pressures, viscosities, temperatures, or other variable factors.

In construction this device consists fundamentally of a closed cylinder containing the oil, within which there is a concentric barrel, through which the oil is measured by the ton. The space between the measuring barrel and the outer body is divided into two chambers, one containing the inlet valves to the measuring barrel and the other housing the delivery valves. Thus the flow through the meter is always in one direction.

Piston valves are used to which plunger rods are attached. At a certain point in each stroke the measuring piston makes contact with the plunger rods of the inlet valve and delivery valve at one end of the cylinder and moves them against spring pressure until, at a predetermined point, a trip falls and holds the valves in place. Simultaneously, on the other side of the piston, a trip is released, permitting the pair of valves at the opposite end of the cylinder to assume their defined position under their spring action. It will be readily understood that the valve operation requires the inlet valve on one side of the piston to be open when the inlet valve on the other side is closed, and the delivery valves to be correspondingly taken care of. There is nothing special or intricate in this.

Of importance, and of particular design, are the adjustments, two in number, namely, the thermostatic control and the manual control. The first of these consists of a small metal tube containing a liquid of similar coefficient of expansion as the liquid that is to be metered. It is permanently fixed at one end, with the other end floating and carrying the valve-trip bar. Consequently the temperature changes cause the valves at one end of the meter to open proportionately earlier or later, thus having the effect of increasing or reducing the volume measured by the piston on each stroke. In this way the measurement by weight-gallon is maintained constant. Manual control is virtually a factory adjustment, being made on the valve trip at the other end of the measuring cylinder.

For any definite grade of oil the thermostatic control can be made exact. To take care of the varying grades of oil which a ship may have to purchase as it bunkers at different parts, the engineer should order a series of thermostatic controls to be charged with different liquid at the factory. (*Motorship*, vol. 8, no. 6, June, 1923, pp. 426–427, *d*)

MOTOR-CAR ENGINEERING (See Special Processes)

Eight-in-Line Engine Packard Chassis, J. Edward Schipper. The new Packard chassis incorporates two features novel in American motor-car construction, namely, the eight-in-line engine and four-wheel brakes. The eight-in-line engine has been selected to replace the twin six because of its overlapping power impulses, its inherently good balance with consequent freedom from vibration periods within the range of driving speed, and its relative accessibility.

The engine is $3^3/_8$ in. by 5 in., block cast and of the L-head type, with a compression ratio of 4.51. It was designed to develop 85 hp. at 3000 r.p.m.

The engine parts generally are of the usual type with the exception of the crankshaft. In this the crankpins for cylinders Nos. 3, 4, 5, and 6 lie in one plane at right angles to the common plane of the crankpins for cylinders Nos. 1, 2, 7, and 8, and it is claimed that such an arrangement eliminates excessive vibration. The nine-bearing construction is used to provide a small intervening span between the main bearings giving a rigid support to the crank shaft, in addition to which a vibration damper is fitted to the front end of the crankshaft. (*Automotive Industries*, vol. 48, no. 24, June 14, 1923, pp. 1266–1274, illustrated, *d*)

The New Saturation Problem, Alvan Macauley. The author, who is president of the Packard Motor Car Company, discusses the physical saturation of the country with motor cars. By this he means that the number of motor cars already in existence has become so large as to make driving difficult and unpleasant in many instances.

Already traffic conditions are forcing voluntary limitations on the use of automobiles. Many suburban residents have stopped bringing their cars into the city; many city owners will not use them at all during certain hours; in the shopping and theatrical districts of New York, walking, even in bad weather, is preferred by some to the exasperating experience of trying to get to destination in a taxicab.

Above all, the problems of public safety cannot be dodged. It is not relevant to blame the "jay walker." It is not relevant to flourish statistics showing that fewer people die in automobile accidents than of measles. It is not relevant to prove that politics and the police department are responsible.

Many remedies have been suggested but they will all be merely temporary, as they do not go to the root of the difficulty.

Repetitions of New York's traffic difficulties can be avoided—and must be. The fundamental traffic problem is the problem of the city plan. Traffic crowding, delays, accidents, high taxes for police purposes and relief streets, high costs of deliveries of food—all these problems and many others can be traced in large measure to the planlessness of our cities.

A few municipal authorities and city-planning engineers are studying the unexpected increase of automobile traffic and the provisions which should be made for it. Too few public officials and public bodies realize what is needed. They do not see yet that it is cheaper to plan ahead than to cut new avenues through big buildings or rear bridges many miles long over crowded streets.

It is up to the automobile industry to face this new saturation problem frankly and intelligently, and to do all in its power to help plan and build our cities so that our industry can safely and effectively serve them. (*Automotive Industries*, vol. 48, no. 23, June 7, 1923, pp. 1231, *pA*)

PHYSICS

The Reduction of All Physical Dimensions to Those of Space and Time, Prof. A. P. Mathews. The author believes that ultimately all physical entities of the universe will be expressed in terms of four dimensions—three of space and that of time. With these four dimensions the whole of the physical universe could be expressed in equations of a four-dimensional space with the sole reservation that this would leave out the fifth dimension, namely, psychism, by which the author means that property of matter at present neglected by the physicists which is exhibited in its clearest form in living things and which shows itself in thought and consciousness in such large psychic units as human beings.

From this the author proceeds in an attempt to show how all the physical phenomena of the world may be expressed in dimensions of space and time. He considers for this the dimensions of quantity of electricity, dimensions of magnetism or magnetic flux, and of ethereal constants.

The reduction of physical quantities to space and time is claimed to make clear the nature of energy, which the author expresses as $(E) = \left(\frac{L^5}{T^2}\right) = \left(\frac{L^3}{T} \times L^2 \times \frac{1}{T}\right)$ = magnetic flux $\times$ electric quantity per second.

In other words, all energy of whatever kind, potential or kinetic, is the product of magnetic flux and electric current, or magnetic flux times electric quantity per second, or magnetic flux times electric quantity times a frequency. This magnetic flux may be identified, as is usual, with ether flow (that is, electric quantity times velocity), and electric quantity with ether twist. Hence all energy is in the ether and is nothing else than a certain quantity of twisted ethereal flow or strain.

That potential energy is nothing else than some kind of strain in the ether, the latter being perfectly elastic, is generally supposed. So all the energy of position, whether this be gravitational energy, as in the separation of masses; electrostatic, as in the separation of charges; or chemical, as in the separation of magnetic poles or currents, is nothing else than a strain, twist, or what not in the ether. It is an ethereal phenomenon. It is always and everywhere magnetic flux times electric energy times frequency. Similarly with kinetic energy; for kinetic energy is the expression of inertia and elasticity. Inertia is self-induction. To move an electric charge from rest, or to increase its velocity when in motion, strain in the ether is set up or increased just as in separating unlike charges to make potential energy. The greater the velocity, the greater the mass; i.e., the greater the number of electric charges moved, the greater is this strain. When a moving body or current stops, or is retarded, this strain or energy or deformation is suddenly

released. Consequently all energy, whether kinetic or potential, is ethereal strain. And quantity of energy is quantity of ethereal distortion per second.

Temperature has the dimensions of energy, and is also magnetic flux times electric discharge per second. Temperature is nothing less than the product of magnetism by current.

The author further develops the above ideas by considering the dimensions of a natural physical phenomenon on the basis of an assumption that time is a four-spatial coördinate. If this is so, then mass and energy have the dimensions of volume. On the other hand, if time is kept as a separate entity not to be equated with the length, then energy is more than mass. (*Journal of the Washington Academy of Sciences*, vol. 13, no. 10, May 19, 1923, pp. 195–210, *t*)

POWER-PLANT ENGINEERING

The Yarrow Stationary Water-Tube Boiler

The Yarrow Land-Type Boiler. Description of a Yarrow boiler intended for use in electric power stations, in particular the type installed at the Dunston Power Station of the Newcastle-upon-Tyne Electric Supply Co. The boiler described has been in operation for several months.

Fig. 4 illustrates the general arrangement of the boiler at Dunston, which is of the Yarrow straight-tube type, fitted with a superheater and air heaters, the elements comprising a steam drum 5 ft. in diameter and four water drums. The steam drum and the water drums are connected by $1^3/_4$-in. cold-drawn steel tubes, which are expanded and bell-mouthed at each end by pneumatic power in accordance with the usual practice in this type of boiler. The outside water drums are 30 in. in diameter and are connected to the steam drum by twelve rows of tubes, while the two drums nearer the fire, which are 23 in. in diameter, are joined to the steam drum by four rows of tubes. The total evaporating surface of the boiler is 9100 sq. ft., of which 2135 sq. ft. are provided in the two tube nests on either side of the fire and 6965 sq. ft. in the outer nests.

At each side of the boiler between the two nests of tubes one-half of the superheater is installed, the steam passing first through one and then crossing by a pipe to the other.

The superheater, which has a heating surface of 2000 sq. ft., is composed of a number of U-tubes, $1^1/_8$ in. in diameter, which are expanded and bell-mouthed into a circular drum, access to the tube ends being obtained from inside the drum—which may be entered by a manhole in the usual way. The superheater is of the self-draining type, and is designed so that the steam makes two passages through each part, or four passages in all. The drop in steam pressure through each part under the highest rates of evaporation does not exceed 1 lb. per sq. in.

Features of the boiler are the large combustion space of 1800 cu. ft. and the extent of the evaporating surface which is exposed to the direct radiation of the fire. An examination of the combustion chamber after the boiler had been in commission for some months showed that the tubes had remained quite straight.

The air heaters are placed in the uptake. They are of the tubular type and contain 1504 tubes 8 ft. in length and $2^3/_4$ in. in external diameter, the combined heating surface being 8631 sq. ft. The gases pass through the inside of the tubes, and the air to the grates is heated by passing over the outside of the tubes. The air to the grates is not only heated by passing through the air heater itself, but it also absorbs additional heat during its passage over the boiler casings, both to and from the heater. By this means the boiler casing is used to assist in heating the air and at the same time the radiation losses through the casing are reduced.

In tests the normal output of the boiler is 64,000 lb. of steam from and at 212 deg. fahr. The trials, however, were made from a feed temperature of 80 deg. fahr. to superheated steam of about 720 deg. fahr., which at the working pressure of 215 lb. per sq. in. corresponds to a degree of superheat of about 330 deg. fahr. This feedwater temperature was used on the trials and was fixed to meet certain specified conditions, but in general practice it is considerably higher. An output of 64,000 lb. of water evaporated per hour from and at 212 deg. fahr. corresponds to an evaporation of rather more than 7 lb. of water from and at 212 deg. fahr. per hour per square foot of generating surface. At this rate of evaporation, approximately 30 lb. of coal were burned per square foot of grate area per hour. An analysis of coal was obtained in accordance with recognized methods, and an efficiency on the normal load trial of 86 per cent was obtained, the analysis of the waste gases showing 12.6 per cent of CO_2. During the overload trials the output obtained was approximately 90,000 lb. of water evaporated per hour from and at 212 deg. fahr., and it was shown that the limit of output on this trial was determined by the capacity of the forced-draft fan, which had not been designed for so high an overload demand; otherwise there was no reason why the boiler should not have been worked up to a greater output.

There is one feature in the trials which is particularly interesting, namely, the difference between the draft at the funnel base and that over the grate. At normal load the draft at the funnel base was

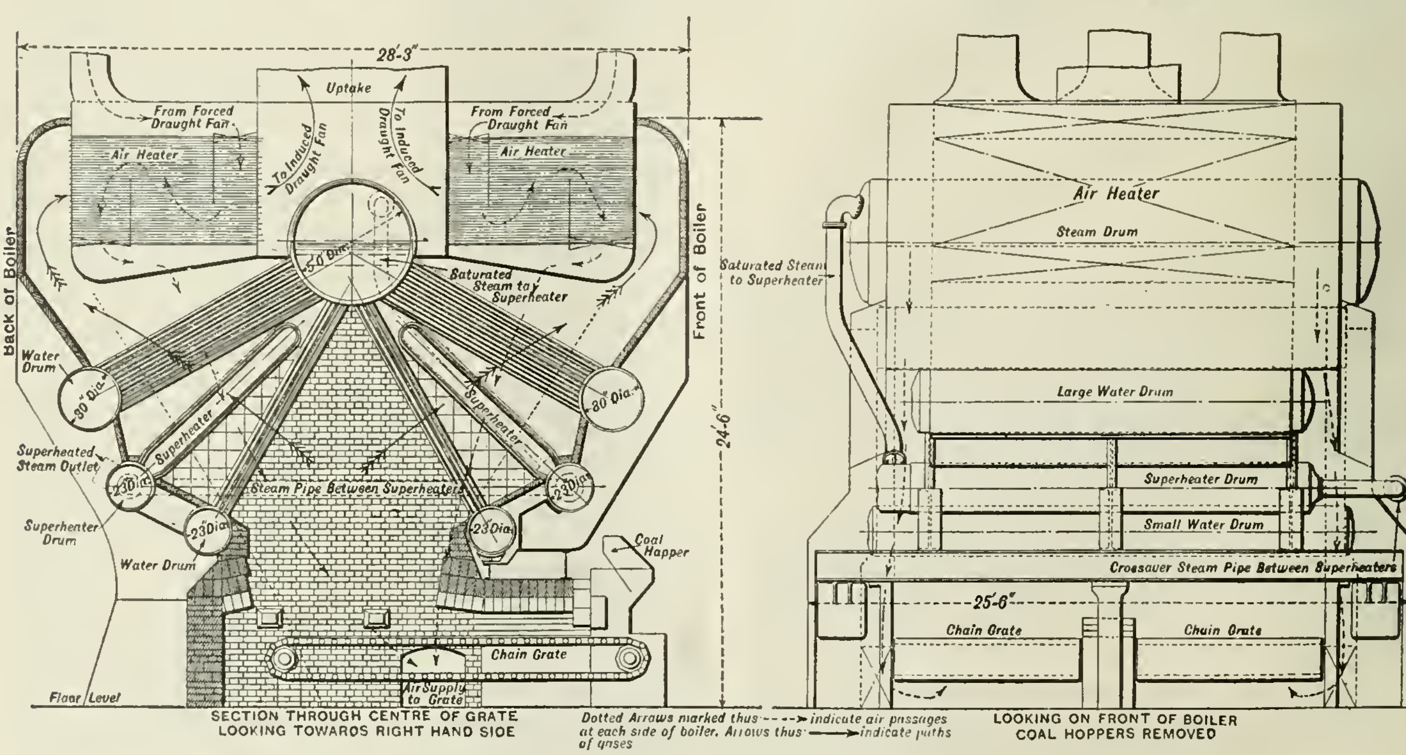

Fig. 4 Yarrow Water-Tube Boiler at the Dunston Electric Power Station

0.32 in. of water, while a similar reading taken over the grate was 0.25 in. This small difference is to be attributed by the large area provided for the passage of the gases from the furnace, through the nests of tubes to the chimney, as well as to the absence of baffles or other restriction. Possibly the absence of bird-nesting experienced with this boiler is to some degree to be accounted for by the slow velocity of the gases through the tubes.

At normal load the temperature of the flue gases was reduced by 220 deg. fahr. by the air heater, while the average temperature of the air passing under the grate was about 300 deg. fahr. So far no injurious effects have been experienced on the grates or the brickwork or any other part of the boiler by air temperatures up to 362 deg. fahr., which is the limit reached during the trials, and it would appear that the grates might have been worked at a still higher temperature without harm.

The Dunston boiler was designed for coal firing, but other boilers illustrated in the original article have been arranged also for oil or powdered fuel. The original article shows also a boiler with superheater on one side, and likewise a boiler arranged with the downtake to economizer. (*The Engineer*, vol. 135, no. 3520, June 15, 1923, pp. 638–640, 7 figs., *dA*)

N.E.L.A. Report on Prime Movers

Report of Prime Movers Committee, National Electric Light Association. Only a few parts of this interesting document can be abstracted owing to lack of space.

Higher Steam Pressures and Temperatures. Considerable progress has been made toward the adoption of higher pressures and temperatures in new central-station plants since last year's report was written. A few plants have been operating with 350 lb. and 600 to 650 deg. fahr. at the boiler for several years, and these conditions have been adopted in additions now being made to existing plants.

One company, after several years' operating experience with 350 lb. at the boiler and 300 lb. at the turbine, is building a new plant using 400 lb. at the boiler. One of the large operating companies is building a plant designed for 400 lb. at the boiler and another a plant for 550 lb. In the latter case the boilers themselves can be operated up to 650 lb. The steam temperature in these later installations ranges between 650 to 750 deg. fahr.

In considering the improvement in economy which can be gained through the use of higher pressures and temperatures, the possibilities in the use of lower vacuum should always be kept in view. The temperature range worked through is of primary importance, and it may be possible under certain conditions to extend this range with a smaller increase in first cost by working at a lower vacuum than by increasing pressure and temperature. In studying this problem the relationship of the yearly load curve to the condensing-water temperature must be considered. The sub-committee on condensing equipment is studying these conditions and expects to discuss the problem in its report.

The high-pressure plants now under construction or about to be constructed represent a considerable advance in American practice. Great credit is due to the engineers and executives who have taken these forward steps in development. In a few years there will be available a considerable quantity of actual operating data on items that are, now, more or less a matter of conjecture. It is felt that in going beyond 400 lb. pressure at present, a field is being entered where little is known about the operating difficulties which may be encountered, and many engineers feel that it would be well not to advance too rapidly until more is known about these difficulties and more actual operating experience is available.

On the other hand, it unquestionably would be an error in judgment to continue installing plants designed for 200 to 250 lb. pressure at the boiler without giving due consideration to the possibilities latent in the use of higher pressures. The successful operation of 300-lb. and 350-lb. plants over a period of years shows unquestionably the wisdom of having gone to a higher pressure than the old standard.

Attention is directed to a paper presented at the 1922 Annual Meeting of The American Society of Mechanical Engineers by Geo. A. Orrok, Mem. A.S.M.E., on The Commercial Economy of High Pressure and High Superheat in the Central Stations. Mr. Orrok's article covers the effect of regeneration as well as the effect of increased temperatures and pressures.

There is quoted in full in the original report an article by L. E. Kemp which appeared in the *Electrician* of June 30, 1922. This article gives an analysis of this problem from the English viewpoint. Certain editorial comments are made on this article and additional curves are given which present Mr. Kemp's conclusions in a rather different manner.

Station Piping. Preliminary investigation of the subject of pressure drop in steam lines was started by the Committee and up to the present time a limited amount of data for specific cases has been made available by the member companies.

It would seem from some of the data submitted that considerable variation in the results obtained will occur unless measurements are made more carefully than has been the case in some instances. This is particularly true in the case of drop through reducing fittings, venturi valves, elbows, tees, and bends. Gage connections at points where direction of flow changes should be so located as to get the average pressure. The crowding of steam toward the outside of turns of all kinds is probably responsible for many discordant results. In the matter of non-return valves, checks, etc., allowance must be made for the pressure required to float the disks. Large drops through valves and fittings are not necessary. Proper design will reduce pressure losses to comparatively small amounts. The extent to which such losses can be reduced is indicated by the following tabulation which gives data for one make of throttle valve.

	Steam flow, lb. per hr.	Pressure, lb.	Temperature, deg. fahr.	Pressure drop, lb.
20-in Schutte & Koerting throttle valve built in 1915...........	425,000	208	541	11.0
	225,000	208	541	3.5
18-in. Schutte & Koerting valve built at a later date..........	320,000	212	525	1.0

The report also contains a discussion of the power-station heat balance, dealing in particular with power-station auxiliaries. This is not suitable for abstracting. Among other things this part of the report contains description of various auxiliaries, together with a brief bibliography. (*National Electric Light Association*, Report presented at the New York Convention, June, 1923, 78 pp., 87 figs., *gd*)

The Kestner Vertical Water-Tube Boiler

The Kestner Boiler. Description of a boiler invented by the French engineer, Paul Kestner, and built in England. It consists essentially (Fig. 5) of an upper steam drum 1, and a lower mud drum 2, which are connected together by straight vertical tubes expanded into accurately machined holes. The tubes are arranged in the form of a repeated letter V and there are only two rows.

The feed arrangement is of particular interest. The feed is delivered into a distributing tray 7, from which it overflows at definite points. It then passes down the small circulating tubes and on striking the deflector tray 8, it has its velocity reduced prior to its return to the steam drum by way of the evaporating tubes 4 and 5.

It is claimed that on account of the feed and circulating arrangements very little scaling takes place inside the boiler even when using comparatively hard water. To provide for expansion the boiler is supported by the upper or steam drum which rests on a steel staging 21, and the lower mud drum is supported by the tubes. The circulation tubes 6, are directly heated by the gases and do not produce steam.

The grate 11 is placed on a level with the mud drum 2, and in front of it; the mud drum being shielded from the hot fuel bed and the hot gases by a firebrick wall 12. Above the grate is an inclined arch 13 which is continued up to the tubes, and firebrick baffles 14 are arranged as an extension of the arch in order to fill up the gaps between the tubes. Complete combustion of the fuel takes place under the refractory brick arch, the hydrocarbons distilled off from the fuel bed by the heat of combustion being ignited and burnt under high temperature conditions before they come into contact with the tube surfaces.

To gain access to the interior of the boiler for inspection and cleaning, it is simply necessary to remove two manhole covers. Access may also be gained to the exterior portions of the tubes through a number of openings 20.

The simplicity of the Kestner boiler enables it to be opened up,

cleaned, and inspected in a very short space of time, and there is therefore a considerable reduction in the cost of labor. The ease with which the tubes can be removed and replaced will be understood from Fig. 5. The firebrick slates shown at 10 in Fig. 5 are removable, and can easily be taken off to enable the tubes to be withdrawn, the new tube being placed in position in the same manner. The length of the tubes in the standard boiler is 23 ft., but where head room is of importance the makers supply another type with shorter tubes.

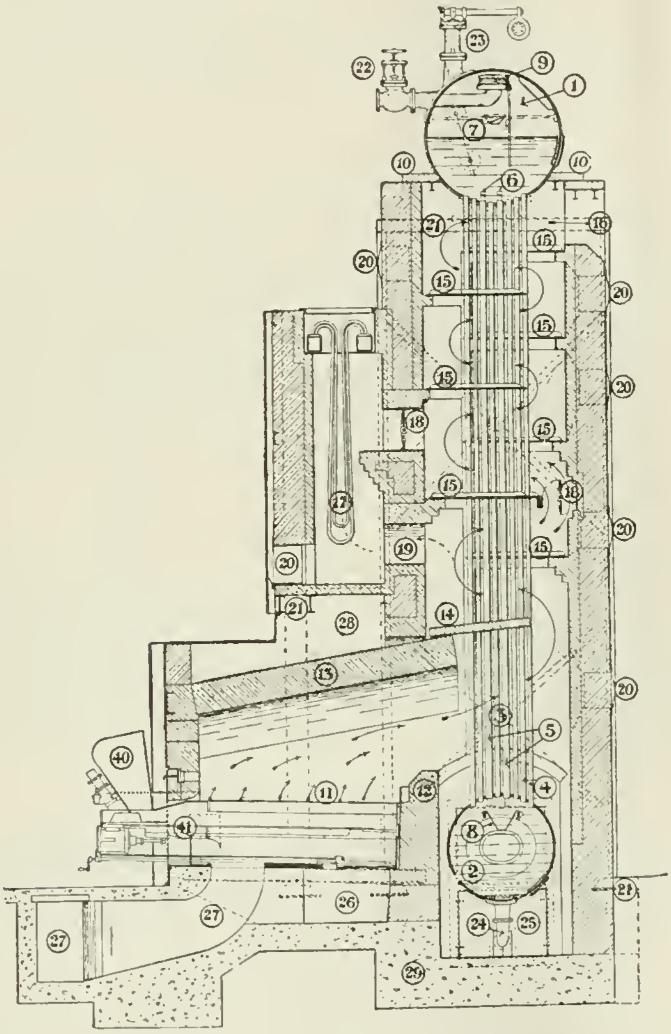

Fig. 5 The Kestner Boiler

For gas firing the Kestner boiler is claimed to be specially suitable, and, where necessary, it can be arranged for use with coal or gas, an extra combustion chamber being provided for the combustion of the latter. It is also suitable for the utilization of waste heat. All the superheater joints are accessible, and any tube expanding or plugging that may be necessary can be carried out outside the boiler setting. Steam can be raised very rapidly, and hogging of the tubes is said to be practically unknown. The boiler is claimed to have a more rapid steam circulation than any other steam generator on the market, thus allowing of a high evaporation per square foot of heating surface and a high rate of combustion of inferior fuels. The hottest gases impinge upon that part of each evaporating tube which only contains water, while the cooler gases make contact with that part of the tube which mainly contains steam. (*The Practical Engineer*, vol. 67, no. 1890, May 17, 1923, pp. 278–279, 4 figs., *d*)

Design Features of New 1200-lb.-Pressure Boilers. Description of an installation designed by the Babcock & Wilcox Co. for the Commonwealth Edison Co. of Chicago for installation at the Calumet Station. In this steam will be furnished at 1200 lb. pressure to an extra-high-pressure turbine which will exhaust at about 300 lb. into the superheater supplying steam to the steam mains feeding the main station turbine. The extra-high-pressure turbo-generator is expected to be of a capacity from 2500 to 3000 kw. The boiler will furnish about 110,000 lb. of steam per hour. The unit is of the inclined-header cross-drum type and comprises a Babcock & Wilcox forced-draft chain-grate stoker 24 ft. wide and 18 ft. 3 in. long, a lower deck of eight-high sections of 2-in. tubes having a setting height of 25 ft. $9^3/_4$ in., a primary and a secondary superheater in an interdeck space 8 ft. $1^1/_4$ in. between decks, an upper deck of seventeen-high sections of 2-in. tubes, two rows of horizontal $3^1/_4$-in. circulating tubes entering a 48-in. cross-drum, and a Babcock & Wilcox steel contraflow economizer. The lower deck is not baffled; the upper deck has a vertical baffle causing the gases to make two passes. The complete unit is about 28 ft. wide, $36^1/_2$ ft. deep, including the economizer, and 45 ft. high above the floor. The heating surfaces have not yet been definitely fixed, but they will be approximately as follows: Boiler, 15,750 sq. ft.; primary superheater, 2120 sq. ft.; secondary superheater, 3300 sq. ft.; economizer, 9230 sq. ft.

One marked difference in the construction of this boiler is in the cross-drum. This drum is a forged steel cylinder, 48-in. diameter with 4-in. walls made up by rolling on a mandrel and swaging the ends.

Drum heads are integral, each with a manhole closed by a 12- by 16-in. manhole fitting. In order that the holes for connecting the circulating tubes to the drum may leave the largest practicable ligaments between circumferential rows of holes, an unusual arrangement of connections has been adopted. At the top of each uptake header two horizontal circulators are connected, but the circulators from each alternate header are bent downward and sidewise so that they are connected to the drum in the same circumferential row as the circulators without such bends. This makes the distance between these circumferential rows about 16 in. In the same way the downtake nipples are not straight but bent so that the two downtake headers are connected to each of those circumferential rows of holes in the drum.

Connections to the drum comprise four 3-in. nozzles for safety valves, a 3-in. nozzle for the saturated steam connection to the lower header of the primary superheater, and two 3-in. nozzles for connections to a feed pipe extending the length of the drum below the water line. (*Power Plant Engineering*, vol. 27, no. 12, June 15, 1923, pp. 637–638, 1 fig., *dA*)

A New Boiler-Feeding Device

The Auto-Thermal Boiler Feed. Description of a novel type of boiler-feed device having the following cycle of operations. All available condensation from steam traps brought by pipes *A*, Fig. 6, together with the necessary make-up feed by the pipe *B* is run into the upper of the two vessels *C*, which is provided with a vapor outlet

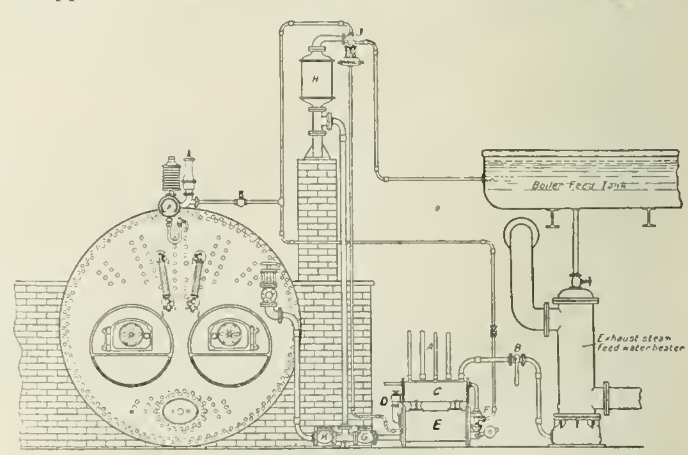

Fig. 6 Auto-Thermal Boiler Feed

and is simply a collector. From this collector the water runs by gravity through the connecting pipe *D*, which is provided with a stop valve and non-return valve, into the lower vessel *E*. An internal float rising with the water line operates the steam valve *F*, which at the psychological moment admits live steam to the vessel, discharges the water through the non-return valve *G*, and lifts it up into the vessel *H* (the feeder) above the boiler. An equilibrium

pipe connects the inside of the lifter with the underside of a diaphragm *J*, by means of which the rise and fall of pressure in the lifter *E*, in performing its functions, is utilized to operate the valves which exhaust or admit live steam to the feeder *H* at the proper time. The mechanism is so arranged that when the lifter is discharging under pressure the diaphragm valve is lifted, exhausting the feeder *H* in order to receive the water. On the lifter exhausting when empty, the valve *J* returns to its normal position and steam of full boiler pressure is admitted to the top of the feeder *H*, whence the pressure being equal to that in the boiler, the water gravitates to the boiler by way of the non-return valve *K*: meanwhile, the water is again filling up the lifter *E* and the cycle is repeated.

The perfect working of the appliance is mainly due to the effective way in which the exhausting or admission of steam to the feeder *H* is absolutely controlled by the lifter *E*. Naturally the reliability of the apparatus is also dependent upon the main steam valve *F*. The valve, which is moved by the steam pressure itself, is in turn controlled by a small subsidiary balanced valve. Hence the float is only called up to exert the small effort required to move the balanced valve, the rest of the work being performed by the steam pressure. (*The Iron and Coal Trades Review*, vol. 106, no. 2881, May 18, 1923, p. 747, *d*)

RAILROAD ENGINEERING

Pilliod-Sleeve-Valve Performance on the Monon Railroad. Date from an initial report on the performance of a Monon Mikado-type locomotive equipped with Pilliod valves.

This valve arrangement comprises a pair of sleeves, each actuated from a different source, which, combined with a piston moving within these sleeves, enables the exhaust and steam admission to the cylinders to be independently controlled. The valve provides for a 95 per cent release at all points of cut-off, thus eliminating excessive compression in the cylinders.

A number of indicator cards taken from the locomotive in regular operation are reproduced in the original article. These in comparison with a card taken on another locomotive of the same class under similar conditions show clearly that at the same point of cut-off the locomotive with Pilliod sleeve valves develops a higher mean effective pressure than the locomotive with ordinary valves. Consequently the Pilliod sleeve valve, in effect, enables the locomotive to develop the same tractive effort as the plain-valve locomotive with a shorter cut-off. In other words, the Pilliod sleeve valves should enable a locomotive to perform the same amount of work with less steam, used more expansively, than a locomotive equipped with an ordinary type of piston or slide valve.

The basis for economy in the use of Pilliod sleeve valves includes of course, other factors that can be more fully appreciated from a study of the thermodynamic theories involved. The theory evolved by Carnot shows that efficiency depends upon the range of temperature in the engine cylinder, and this ideal diagram shows complete expansion and compression of steam. The efficiency of the actual engine can approach this ideal but never equal it. This is due to the fact that in the use of steam in a metal cylinder practical difficulties prevent a realization of the ideal. It is apparent that after the steam is in the cylinder there is but one way to get maximum efficiency, and that is by making its terminal temperature a minimum. This indicates that release should be carried out as near the end of the stroke as possible. With the ordinary locomotive valve release does occur near the end of the stroke when there is a long cut-off but when the reverse lever is moved toward the center, thus shortening the cut-off; the release is also removed further from the end of the stroke, thus increasing compression. In the usual locomotive valve, when the engine is "cutting off" at 25 per cent of the stroke, the release has dropped back to 60 per cent, giving only 60/25 or 2.4 expansions, when under ideal conditions there should be 100/25 or 4 expansions. In this condition, compression occurs at about 40 per cent of the stroke. (*Railway Review*, vol. 72, no. 24, June 16, 1923, pp. 988–992, illustrated, *d*)

REFRIGERATION

The Compression Refrigeration Cycle, W. H. Motz. In the abstract of this article from *Refrigerating Engineering*, vol. 9, no. 9, March, 1923, which appeared on page 366 of the June issue of Mechanical Engineering, it was stated that the amount of ammonia evaporated per minute per ton of refrigeration has been taken for standard conditions as 0.442 lb. It should have read 0.422 lb., as 0.442 lb. of ammonia per ton of refrigeration per minute would not be required unless the condensing temperature was exceedingly high or the evaporation temperature was exceedingly low.

SPECIAL PROCESSES

Making Welded Pressed-Steel Automobile Wheels. Description of a process developed by the Stanley Steel Welded Wheel Corporation, Boston, Mass.

Essentially each wheel consists of a spider made up of two flanges welded together and containing eight spokes welded into pockets formed by depressions in the two flange members. Two of these spiders are butt-welded at the hub portions of adjacent flanges, so that the spokes of one spider will alternate with the spokes of the other. This unit is then assembled into the outer rims, which in their turn are provided with pockets into which the spokes are welded in the final assembling.

The actual presswork is of the usual character and it is the welding that is of particular interest. An automatic machine for spot-welding the wheels is described in the original article. The upper electrode holder is held in a frame that pivots to exert pressure on the weld, this pressure being automatically controlled by cam action. The shaft, by means of which the pressure is transmitted, carries a heavy coil spring and a hand wheel for setting the pressure. The spring is capable of transmitting 600 lb. pressure, and the arrangement for adjusting it is such that foot pressure is not required on the control. The entire cycle of operations in making a spot weld includes depressing the electrode, holding it down under pressure for a given time, switching on the current, breaking the current, and finally releasing the pressure.

After the spokes have been spot-welded through the flanges, two spiders, one outer and one inner, are butt-welded on a special machine.

Pressed-steel automobile wheels are said to weigh about the same as wood-spoked wheels, but they are much stronger. It is also claimed that they increase the life of the tire, which is believed to be due to the fact that the pressed-steel wheel possesses greater heat conductivity and as a result the temperature of the tire is reduced. (*Machinery* (N. Y.), vol. 29, no. 10, June, 1923, pp. 757–760, 8 figs., *d*)

TESTING AND MEASUREMENT

Acoustic Method of Finding Elastic Limit of Metals. According to experiments conducted by the physics department of Lehigh University, Bethlehem, Pa., it is believed that stretching a metal until it squeaks and listening for the squeak with a microphone will give a test showing how much strain that the metal can stand when used in a place of stress, such as a bridge girder or railroad rail. Those conducting the experiments point out that the tests may result in a novel and quick method for determining the elastic limit of metals. Forgings could be tested rapidly before they are put in use.

Several metals have been used in the tests. While the investigators listened through a sensitive microphone similar to the dictaphone for the faintest sound, the metal was subjected to a gradually increasing pull until it broke. It was found that squeaking, rasping sounds were produced after the pull had reached a certain definite value, and this value was different for the various metals used. The tests indicated that the sounds were not produced until the elastic limit of the material had been reached. The work will be continued. (*Iron Trade*, vol. 72, no. 23, June 7, 1923, p. 1671, *e*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general, *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Standard Screw Threads for Bolts, Machine Screws, Nuts, and Commercially Tapped Holes

First Report of Sectional Committee on the Standardization and Unification of Screw Threads

THE long-looked-for report of the Sectional Committee on the Standardization and Unification of Screw Threads is now before the Councils of the Society of Automotive Engineers and The American Society of Mechanical Engineers. Upon approval and adoption by these boards it will be submitted by them to the American Engineering Standards Committee for formal adoption as an American Standard.

This Sectional Committee was organized under the Procedure of the A.E.S.C. in the fall of 1920, the S.A.E. and the A.S.M.E. acting as Joint Sponsors. The Committee's instructions called for a complete review of the Progress Report of the National Screw Thread Commission, which was then being printed. In April, 1921, the members of the Committee began their detailed study of the report and on June 9, 1921, they met for the formal organization of the Committee and the election of officers. Luther D. Burlingame was elected Chairman, Ralph E. Flanders, Vice-Chairman, and Clifford B. LePage, Secretary. Realizing the difficulty of a committee of 25 functioning efficiently in the preparation of a report of this kind, a Working Committee of seven members of the Sectional Committee was immediately appointed. This Working Committee consisted of Ellwood Burdsall, Chairman, Paul W. Abbott, Earle Buckingham, George S. Case, Ralph E. Flanders, George E. Hammann, and Will R. Porter.

After a very careful study of the N.S.T.C. report and numerous meetings, the Working Committee issued its first report to the members of the Sectional Committee in February, 1922. Since that date four additional revised drafts of this report have been prepared and carefully considered by the Sectional Committee. As the report neared its final form the Sectional Committee delegated Messrs. Flanders, Buckingham, Case, and Wells as a special committee to discuss with the National Screw Thread Commission the slight modifications which the Sectional Committee desired to make. The resulting discussions in the meetings of the Commission led to the adoption of modifications in the report which were mutually satisfactory.

Purpose of Present Report

During its early discussion of the report of the Working Committee the Sectional Committee definitely limited the field to be covered by its first report to Screw Threads for Bolts, Machine Screws, Nuts, and Commercially Tapped Holes. A number of considerations prompted this action. In the first place it was desired to put in the hands of American industry promptly one of the tools which it greatly needs, viz., a manual of improved screw-thread practice. In the second place it found that standards for pipe threads, fire-hose coupling threads, and small hose threads had either been passed through the A.E.S.C. procedure or were on the way by other means, so consideration of them was omitted. But one part of the Commission's report therefore remains to be accounted for. This is Section VI, entitled Gages, and Appendix 6, Gages and Methods of Test. By a vote of the Sectional Committee it was decided not to recommend any one particular system of gages or for gaging screw threads but to prepare and issue as a second report a general discussion on this subject in which certain fundamentals only will be laid down.

Critical Comment

The first report of the Sectional Committee on the Standardization and Unification of Screw Threads is merely a selection from and a rearrangement of the material which was originally

Table 1 The Two-Thread Series

1	2	3	4
Identification	Basic Major Diameter (Inches)	Fine Series Threads per Inch	Coarse Series Threads per Inch
0	0.0600	80	..
1	0.0730	72	64
2	0.0860	64	56
3	0.0990	56	48
4	0.1120	48	40
5	0.1250	44	40
6	0.1380	40	32
8	0.1640	36	32
10	0.1900	32	24
12	0.2160	28	24
1/4	0.2500	28	20
5/16	0.3125	24	18
3/8	0.3750	24	16
7/16	0.4375	20	14
1/2	0.5000	20	13
9/16	0.5625	18	12
5/8	0.6250	18	11
3/4	0.7500	16	10
7/8	0.8750	14	9
1	1.0000	14	8
1 1/8	1.1250	12	7
1 1/4	1.2500	12	7
1 1/2	1.5000	12	6
1 3/4	1.7500	12[1]	5
2	2.0000	12[1]	4 1/2
2 1/4	2.2500	12[1]	4 1/2
2 1/2	2.5000	12[1]	4
2 3/4	2.7500	12[1]	4
3	3.0000	10[1]	4

[1] These pitches are suitable for work requiring short engagement where it is not practical to specify tolerances for all conditions. They are not, therefore, included in the succeeding tables.

Table 8 Coarse Thread Series—Free Fit (Class 2)—Screws

1	2	3	4	5	6	7	8	9
		Major Diameter			Pitch Diameter			
Size	Threads per Inch	Maximum[1] (Inches)	Tolerance (Inches)	Minimum (Inches)	Maximum[1] (Inches)	Tolerance[3] (Inches)	Minimum (Inches)	Maximum[2] Minor Diameter (Inches)
1	64	0.0730	0.0038	0.0692	0.0629	0.0019	0.0610	0.0538
2	56	0.0860	0.0040	0.0820	0.0744	0.0020	0.0724	0.0641
3	48	0.0990	0.0044	0.0946	0.0855	0.0022	0.0833	0.0754
4	40	0.1120	0.0048	0.1072	0.0958	0.0024	0.0934	0.0813
5	40	0.1250	0.0048	0.1202	0.1088	0.0024	0.1064	0.0943
6	32	0.1380	0.0054	0.1326	0.1177	0.0027	0.1150	0.0997
8	32	0.1640	0.0054	0.1586	0.1437	0.0027	0.1410	0.1257
10	24	0.1900	0.0066	0.1834	0.1629	0.0033	0.1596	0.1389
12	24	0.2160	0.0066	0.2094	0.1889	0.0033	0.1856	0.1649
1/4	20	0.2500	0.0072	0.2428	0.2175	0.0036	0.2139	0.1887
5/16	18	0.3125	0.0082	0.3043	0.2764	0.0041	0.2723	0.2443
3/8	16	0.3750	0.0090	0.3660	0.3344	0.0045	0.3299	0.2983
7/16	14	0.4375	0.0098	0.4277	0.3911	0.0049	0.3862	0.3499
1/2	13	0.5000	0.0104	0.4896	0.4500	0.0052	0.4448	0.4056
9/16	12	0.5625	0.0112	0.5513	0.5084	0.0056	0.5028	0.4603
5/8	11	0.6250	0.0118	0.6132	0.5660	0.0059	0.5601	0.5135
3/4	10	0.7500	0.0128	0.7372	0.6850	0.0064	0.6786	0.6273
7/8	9	0.8750	0.0140	0.8610	0.8028	0.0070	0.7958	0.7387
1	8	1.0000	0.0152	0.9848	0.9188	0.0076	0.9112	0.8466
1 1/8	7	1.1250	0.0170	1.1080	1.0322	0.0085	1.0287	0.9497
1 1/4	7	1.2500	0.0170	1.2330	1.1572	0.0085	1.1487	1.0747
1 1/2	6	1.5000	0.0202	1.4798	1.3917	0.0101	1.3816	1.2955
1 3/4	5	1.7500	0.0232	1.7268	1.6201	0.0116	1.6085	1.5046
2	4 1/2	2.0000	0.0254	1.9746	1.8557	0.0127	1.8430	1.7274
2 1/4	4 1/3	2.2500	0.0254	2.2246	2.1057	0.0127	2.0930	1.9774
2 1/2	4	2.5000	0.0280	2.4720	2.3376	0.0140	2.3236	2.1933
2 3/4	4	2.7500	0.0280	2.7220	2.5876	0.0140	2.5736	2.4433
3	4	3.0000	0.0280	2.9720	2.8376	0.0140	2.8236	2.6933

[1] Basic diameter.

[2] Dimensions given are figured to intersection of the worn tool arc with a centerline through crest and root. Minimum flat at root equals $1/8 \times p$.

[3] The tolerances specified for pitch diameter are cumulative and include all errors of lead and angle.

published in the Progress Report of the National Screw Thread Commission. Several "paper" changes have been made by the Committee but these did not alter materially the product itself. Any threaded product which meets the specifications laid down by the Progress Report of the National Screw Thread Commission will also meet the specifications of the Sectional Committee's report.

This report does not present a new set of standards for screw threads but rather an extension of existing standards by specifying limiting dimensions for the various sizes and pitches of threads already in common use. It also gives official sanction to certain processes such as oversize drill sizes which have long been established by common use. Altogether it is an attempt to codify the best current practice on screw-thread production. How well this attempt has succeeded can be best learned by its general use in industry.

The Committee's decision to limit the field covered by its first report to threaded parts for holding purposes, such as bolts, nuts, machine screws, and commercially tapped holes, seems to be well founded. When the standard practice codified by this report has had a fair tryout by the American screw-thread industry, given an opportunity for revision or correction if necessary, a long advance will have been made toward the further establishment of standards for threading tools and screw threads for special purposes. Among the latter are included studs, fine threads of large diameter and short engagement, for instance, those which are used for cap nuts on machine tool collars, hub and radiator caps, etc. The Sectional Committee fully realized that the screw-thread field is so broad as to make it impossible to cover the entire field in its first report. Furthermore the experience which it is hoped to gain by the use of its first proposals will be of great value in working out satisfactory standards for other applications.

Since it is impossible for us to reproduce in Mechanical Engineering the complete report of the Sectional Committee, we are printing several sections of this report, including four tables to indicate the complete and altogether satisfactory way in which this Committee now presents the results of its two years' study. The report is now being edited for publication in pamphlet form and it is expected that these pamphlets will be ready for general distribution by August 15. Those desiring copies should apply to The American Society of Mechanical Engineers.

II Form of Thread

The form of thread profile as specified herein, and known previously as the United States Standard or Sellers' Profile, is adopted and shall hereafter be known as the American (National) Form of Thread.

1 Where Used. The American (National) Form of Thread Profile shall be used wherever possible for screw-thread work.

2 Specifications. The basic angle of thread between the sides of the thread measured in an axial plane shall be 60 degrees. The line bisecting this 60 degree angle shall be perpendicular to the axis of the screw thread.

The basic width of flat at the root and crest of the thread form is found as follows:

$$F = \tfrac{1}{8} \times p \text{ or } 0.125 \times p$$

The basic depth of the thread form is found as follows:

$$h = 0.649519 \times p = \frac{0.649519}{n}$$

where p = pitch in inches

n = number of threads per inch.

3 Clearance in Nut at Minor Diameter. A clearance shall be provided at the minor diameter of the nut by removing the thread form at the crest by an amount between one-sixth and one-fourth of the basic thread depth.

4 Clearance in Nut at Major Diameter. A clearance at the major diameter of the nut shall be provided by decreasing the depth of the truncation triangle any desired amount down to one-third of its theoretical value.

Table 9 Coarse Thread Series—Free Fit (Class 2)—Nuts

1	2	3	6	7	8	9	10	11
			Pitch Diameter			Minor Diameter		
Size	Threads per Inch	Minimum[1,2] Major Diameter (Inches)	Minimum[1] (Inches)	Tolerance[3] (Inches)	Maximum (Inches)	Minimum (Inches)	Tolerance (Inches)	Maximum (Inches)
1	64	0.0730	0.0629	0.0019	0.0648	0.0561	0.0017	0.0578
2	56	0.0860	0.0744	0.0020	0.0764	0.0667	0.0019	0.0686
3	48	0.0990	0.0855	0.0022	0.0877	0.0764	0.0023	0.0787
4	40	0.1120	0.0958	0.0024	0.0982	0.0849	0.0027	0.0876
5	40	0.1250	0.1088	0.0024	0.1112	0.0979	0.0027	0.1006
6	32	0.1380	0.1177	0.0027	0.1204	0.1042	0.0034	0.1076
8	32	0.1640	0.1437	0.0027	0.1464	0.1302	0.0034	0.1336
10	24	0.1900	0.1629	0.0033	0.1662	0.1449	0.0045	0.1494
12	24	0.2160	0.1889	0.0033	0.1922	0.1709	0.0045	0.1754
1/4	20	0.2500	0.2175	0.0036	0.2211	0.1959	0.0054	0.2013
5/16	18	0.3125	0.2764	0.0041	0.2805	0.2524	0.0060	0.2584
3/8	16	0.3750	0.3344	0.0045	0.3389	0.3073	0.0068	0.3141
7/16	14	0.4375	0.3911	0.0049	0.3960	0.3602	0.0077	0.3679
1/2	13	0.5000	0.4500	0.0052	0.4552	0.4167	0.0084	0.4251
9/16	12	0.5625	0.5084	0.0056	0.5140	0.4723	0.0090	0.4813
5/8	11	0.6250	0.5660	0.0059	0.5719	0.5266	0.0098	0.5364
3/4	10	0.7500	0.6850	0.0064	0.6914	0.6417	0.0109	0.6526
7/8	9	0.8750	0.8028	0.0070	0.8098	0.7547	0.0120	0.7667
1	8	1.0000	0.9188	0.0076	0.9264	0.8647	0.0135	0.8782
1 1/8	7	1.1250	1.0322	0.0085	1.0407	0.9704	0.0154	0.9858
1 1/4	7	1.2500	1.1572	0.0085	1.1657	1.0954	0.0154	1.1108
1 1/2	6	1.5000	1.5917	0.0101	1.4018	1.3196	0.0180	1.3376
1 3/4	5	1.7500	1.6201	0.0116	1.6317	1.5335	0.0216	1.5551
2	4 1/2	2.0000	1.8557	0.0127	1.8684	1.7594	0.0241	1.7835
2 1/4	4 1/2	2.2500	2.1057	0.0127	2.1184	2.0094	0.0241	2.0335
2 1/2	4	2.5000	2.3376	0.0140	2.3516	2.2294	0.0270	2.2564
2 3/4	4	2.7500	2.5876	0.0140	2.6016	2.4794	0.0270	2.5064
3	4	3.0000	2.8376	0.0140	2.8516	2.7294	0.0270	2.7564

[1] Basic diameter.

[2] Dimensions given are allowable only with tap having theoretically sharp corners. Threaded hole must not reject correct basic "Go" gage by interference with rounded roots due to worn tap. Minimum flat at root equals $\frac{1}{24} \times p$.

[3] The tolerances specified for pitch diameter are cumulative and include all errors of lead and angle.

Table 17 Fine Thread Series—Free Fit (Class 2)—Nuts

1	2	3	6	7	8	9	10	11
			Pitch Diameter			Minor Diameter		
Size	Threads per Inch	Minimum[1] Major Diameter[2] (Inches)	Minimum[1] (Inches)	Tolerance[3] (Inches)	Maximum (Inches)	Minimum (Inches)	Tolerance (Inches)	Maximum (Inches)
0	80	0.0600	0.0519	0.0017	0.0536	0.0465	0.0013	0.0478
1	72	0.0730	0.0640	0.0018	0.0658	0.0580	0.0015	0.0595
2	64	0.0860	0.0759	0.0019	0.0778	0.0691	0.0017	0.0708
3	56	0.0990	0.0874	0.0020	0.0894	0.0797	0.0019	0.0816
4	48	0.1120	0.0985	0.0022	0.1007	0.0894	0.0023	0.0917
5	44	0.1250	0.1102	0.0023	0.1125	0.1004	0.0025	0.1029
6	40	0.1380	0.1218	0.0024	0.1242	0.1109	0.0027	0.1136
8	36	0.1640	0.1460	0.0025	0.1485	0.1339	0.0030	0.1369
10	32	0.1900	0.1697	0.0027	0.1724	0.1562	0.0034	0.1596
12	28	0.2160	0.1928	0.0031	0.1959	0.1773	0.0039	0.1812
1/4	28	0.2500	0.2268	0.0031	0.2299	0.2113	0.0039	0.2152
5/16	24	0.3125	0.2854	0.0033	0.2887	0.2674	0.0045	0.2719
3/8	24	0.3750	0.3479	0.0033	0.3512	0.3299	0.0045	0.3344
7/16	20	0.4375	0.4050	0.0036	0.4086	0.3834	0.0054	0.3888
1/2	20	0.5000	0.4675	0.0036	0.4711	0.4459	0.0054	0.4513
9/16	18	0.5625	0.5264	0.0041	0.5305	0.5024	0.0060	0.5084
5/8	18	0.6250	0.5889	0.0041	0.5930	0.5649	0.0060	0.5709
3/4	16	0.7500	0.7094	0.0045	0.7139	0.6823	0.0068	0.6891
7/8	14	0.8750	0.8286	0.0049	0.8335	0.7977	0.0077	0.8054
1	14	1.0000	0.9536	0.0049	0.9585	0.9227	0.0077	0.9304
1 1/8	12	1.1250	1.0709	0.0056	1.0765	1.0348	0.0090	1.0438
1 1/4	12	1.2500	1.1959	0.0056	1.2015	1.1598	0.0090	1.1688
1 1/2	12	1.5000	1.4459	0.0056	1.4515	1.4098	0.0090	1.4188

[1] Basic diameter.

[2] Dimensions given are allowable only with tap having theoretically sharp corners. Threaded hole must not reject correct basic "Go" gage by interference with rounded roots due to worn tap. Minimum flat at root equals $\frac{1}{24} \times p$.

[3] The tolerances specified for pitch diameter are cumulative and include all errors of load and angle.

III Thread Series Adopted

Two thread series are adopted,—a coarse and a fine. The Coarse-Thread Series is the present "United States Standard" supplemented in the sizes below one-fourth inch by the standard established by The American Society of Mechanical Engineers (A.S.M.E.) in 1907. The Fine-Thread Series ($^1/_4$ inch to $1^1/_2$ inches inclusive) is in accordance with the present "Regular Screw-Thread Series of the S.A.E: Standard for Screw-Threads" established by The Society of Automotive Engineers (S.A.E.) in 1911, supplemented in sizes below one-fourth inch by the Fine-Thread Series established by The American Society of Mechanical Engineers (A.S.M.E.).

These two series are specified in Table 1.

IV Classification of Fits

1 Description

There are established herein for general use four distinct classes of screw-thread fits as specified in the following brief outline. The examples given under each class of fit are for the purpose of illustration only.

Loose Fit (*Class 1*) Recommended as a commercial standard for tapped holes in the numbered sizes only. May be used with screws of other classes to obtain quality of fit desired. (See Appendix C.)

Free Fit (*Class 2*) Includes the great bulk of screw-thread work of ordinary quality of finished and semi-finished bolts and nuts, etc. (Called "Medium Fit Regular" in the N.S.T.C. "Progress Report.")

Medium Fit (*Class 3*) Includes the better grade of interchangeable screw-thread work, uch ass automobile bolts and nuts (Called "Medium Fit Special" in N.S.T.C. "Progress Report").

Close Fit (*Class 4*) Includes screw-thread work requiring a fine snug fit, somewhat closer than the medium fit, such as high grade aircraft parts, etc. In this class of fit selective assembly of parts may be required. It is not considered practicable as a commercial standard for tapped holes of the numbered sizes.

2 A Second Method of Obtaining Medium Fit (Class 3)

A detailed examination of the tolerances given in Tables 3, 4 and 5 will indicate that the same quality of fit as given by Medium Fit screws and threaded holes can be obtained by using screws to Close Fit tolerances in holes made to Free Fit tolerances, or vice versa. The general adoption of this practice will reduce the variety of taps, gages, threaded parts, etc., required to be carried in stock. However, the combination of Free and Close Fits should be used in place of Medium Fit only when the substitution is understood and agreed to by all parties concerned.

4 General Specifications

The following general specifications will apply to all classes of fits specified in the body of the report. For special specifications applying to the Loose Fit class see Appendix C.

(*a*) *Uniform Minimum Nut.* The pitch diameter of the minimum threaded hole or nut corresponds to the basic size, variations being permitted above the basic size. The major and minor diameters of the minimum nut are also uniform for all classes of fit.

(*b*) *Uniform Tap Drill Sizes.* The maximum and minimum minor diameters and the consequent minor diameter tolerances are the same for all nuts of a given size for all classes of fit. This permits uniform tap drill sizes for all classes of fit.

(*c*) *Uniform Major and Minor Diameter of Screws.* The maximum and minimum major and minor diameters are the same for all screws of a given size for all classes of fit herein tabulated.

(*d*) *Length of Engagement.* The tolerances herein determined are based on a length of engagement not to exceed the nominal diameter of the thread. Where greater lengths of engagement are required a corresponding increase in the accuracy of lead and thread form is necessary, which may be obtained by the provision of selection of more accurate threading tools, and the use of longer "Go" gages.

(*e*) *Rounded Root Forms.* The crest clearances allowed are such as to permit rounded root forms in both nut and screw. These may be formed either by tools purposely rounded or rounded as a result of wear in use. For the limits of this permissible rounding see Pages 28 and 29, Par. 6 and Par. 7.

Roller Chains and Sprockets

Report of the Joint Committee Which is Composed of Representatives of the S.A.E., the A.G.M.A., and the A.S.M.E.

The organization of a roller-chain committee was approved by the Council of The American Society of Mechanical Engineers at the Spring Meeting of the Society in 1917. The Committee was accordingly organized at Indianapolis, Ind., September 14, 1917. Its second meeting and all subsequent meetings have been held in conjunction with the Roller Chain Division of the Society of Automotive Engineers. At a later date the Sprocket Committee of the American Gear Manufacturers Association was invited to coöperate in the standardization work of the Joint Committee. The Committee will welcome suggestions for corrections or additions to this report. These should be addressed to the Secretary, Geo. M. Bartlett, in care of the Society, 29 W. 39th St., N. Y. City.

Recommendations of the Committee, relating to the standardization of chains and sprockets which have been approved by the Council of the A.S.M.E. and published in the September, 1921, issue of Mechanical Engineering, are as follows:

1 Series of Pitches
2 Roller Diameters
3 Pin Diameters
4 Thickness of Side Plates
5 Widths of Narrow and Wide Series
6 Heavy, Medium, and Light Series
7 Names of Chain Parts
8 Tolerance for Chain Length
9 Measuring Load
10 Test Load
11 Uniform System of Numbering Chains
12 Thickness and Chamfer of Sprocket Teeth
13 Standard Tooth Form
14 Range of Teeth for Each Cutter
15 Number of Teeth on Which to Base Each Cutter
16 Sprocket-Cutter Outlines
17 Outside Diameters for Sprockets
18 Thickness of Cutters.

New Recommendations

The following proposed standards have been approved at meetings of the Joint Roller Chain Committee and are now before the Council of The American Society of Mechanical Engineers for approval and adoption.

19 The *thickness of center plates* for double, triple, and quadruple chains shall be equal to two thicknesses of the regular inside plates as used in the single standard chain.

20 The *minimum breaking strength* of standard chains, when used for publication, shall be $105{,}000 \times (\text{Pin Diam.})^2 - 700$ lb.

21 The following note is to be attached to the formula for minimum breaking strengths.

Note: These are the loads at which the chains may break or become permanently stretched. The actual *working* loads may range from $^1/_6$th to $^1/_{50}$th of the ultimate strength, depending upon the speed, teeth in wheels, conditions of lubrication, and pulsations arising from either power or load end. Chains should not be selected on the basis of breaking strengths.

22 Revise the *standard measuring load* from "1 per cent of the *average* breaking strength" to 1.25 per cent of the *minimum* breaking strength. Reason: The minimum breaking strength is given by a formula—the average breaking strength is not.

23 Revise the *standard test load* from "$^1/_3$ of the *average* breaking strength" to 40 per cent of the *minimum* breaking strength. Reason: same as for 22.

24 Revise the standard nomenclature with respect to the terms "assembled pins," "pin link," and "connecting link" to agree with that given below under the heading Roller-Chain Nomenclature.

25 Four *types of sprocket cutters* to be recognized, namely:

Space Cutters, of which five will be required to cut from 7 teeth up for any given roller diameter. The ranges to be respectively 7–8 teeth, 9–11 teeth, 12–17 teeth, 18–34 teeth, 35 teeth and over. The use of less than 7 teeth is discouraged, but when necessary single-purpose cutters of this type are to be used.

Straddle Cutters, of which two will be required to cut from 7 teeth up for any given pitch and roller diameter. Cutter B is recommended for 17 teeth and under (or for more than 17 teeth if a low pressure angle is desired). Cutter A is recommended for 18 teeth

and over (or for less than 18 teeth if a large pressure angle is desired and the arc of contact between chain and sprocket is fairly large).

Hobs, of which only one will be required to cut any number of teeth for a given pitch and roller diameter.

Fellows Cutters, for use on the Fellows gear shaper, of which only one will be required to cut any number of teeth for a given pitch and roller diameter.

26 All *cutters to be marked* giving pitch, roller diameter, and range of teeth to be cut.

27 *Sprocket Cutter Bores* (recommended practice) to be approximately:

$$0.7\sqrt{\text{Width of cutter} + \text{roller diam.}} + 0.7\,P$$

where P is the pitch. See Table 8.

28 *Minimum Outside Diameters of Space Cutters* for 35 teeth and over (recommended practice) to be approximately:

$$1.2\,(\text{Bore} + \text{roller diam.} + 0.7\,P) + 1\text{ in.}$$

See Table 1.

29 Minimum outside diameters of space cutters for less than 35 teeth (recommended practice) to be as per Table 1.

30 *Minimum Outside Diameters of Straddle Cutters* (recommended practice) to be same as for space cutters for 35 teeth and over. See Table 4.

31 *Size of Keyways* in cutters to be in accordance with present prevailing cutter-arbor practice as given in Table 8.

32 *Number of Cutting Teeth in Sprocket Cutters* to be left to the individual cutter makers.

33 The *standard tooth form for block and twin-roller chains* shall follow the same essential specifications as for standard roller chains with the same angle of bend.

34 Recommended *widths of cutters* as per Table 8.

35 Recommended *designations* for the four principal types of sprockets are as follows:

- Type A—plain plate
- Type B—single hub
- Type C—double hub
- Type D—detachable hub

36 *Revised Sprocket-Tooth Form.* The Joint Committee now submits herewith a proposed modification of the standard sprocket-tooth form as passed upon by the Technical Sub-Committee, and approved at the meeting of the Joint Committee held in New York, January 8, 1923.

In the original design very careful consideration was given to the working arcs of the teeth. The exact height of the tooth was set in an empirical manner, as it was not an important operating element. Subsequent developments have indicated that the long tooth restricted the range of teeth that could be covered by a given cutter, whereas it seemed desirable to increase this range for certain special cases. This was accomplished by shortening the tooth and giving greater clearance between the roller and the point of the tooth.

Also the probability of an increased use of hobs and Fellows cutters for generating the teeth has increased the desirability of modifying the angle of tooth gap for larger numbers of teeth so as to conform more closely to the generating process and at the same time to produce a desired increase in pressure angle for the larger sprockets.

Roller-Chain Nomenclature

Roller Link. An inside link consisting of two inside plates, two bushings, and two rollers.

Pin Link. An outside link consisting of two pin-link plates assembled with two pins.

Inside Plate. One of the plates forming the tension members of a roller link.

Pin-Link Plate. One of the plates forming the tension members of a pin link.

Pin. A stud articulating within a bushing of an inside link and secured at its ends by the pin-link plates.

Bushing. A cylindrical bearing in which the pin turns.

Roller. A ring or thimble which turns over a bushing.

Assembled Pins. Two pins assembled with *one* pin-link plate.

Connecting Link. A pin link with one side plate detachable.

Connecting-Link Plate. The detachable pin-link plate belonging to a connecting link.

Offset Link. A link consisting of two offset side plates assembled with a bushing and roller at one end and an offset-link pin at the other.

Offset-Link Pin. A pin used in offset links.

Design of Standard Sprocket Tooth

P = pitch; D = nominal roller diameter; T = number of teeth

$$D' = 1.005D + 0.003\text{ in.};\quad A = 35^\circ + \frac{60}{T};\quad A' = 35^\circ - \frac{120}{T};$$

$$B = 18^\circ - \frac{56}{T};$$

$$ac = 0.8D;\quad M = 0.8D\cos\left(35^\circ + \frac{60}{T}\right);$$

$$N = 0.8D\sin\left(35^\circ + \frac{60}{T}\right)$$

$$J = 0.8D\sin\left(35^\circ - \frac{120}{T}\right);\quad K = 0.8D\cos\left(35^\circ - \frac{T}{120}\right)$$

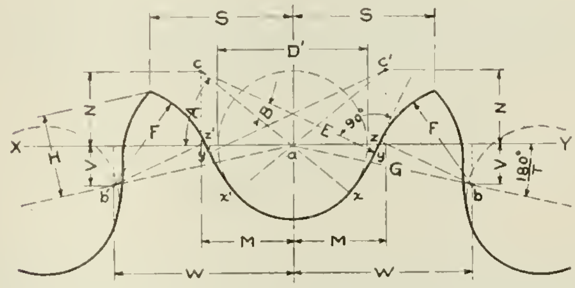

Fig. 1 Tooth Form

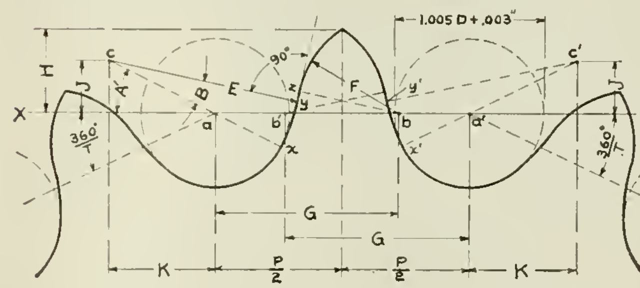

Fig. 2 Tooth Form

$$E = 1.3025D + 0.0015\text{ in.}$$

$$\text{Chord } xy = (2.605D + 0.003)\sin\left(9^\circ - \frac{28}{T}\right)$$

$$yz = D\left[1.24\sin\left(17^\circ - \frac{64}{T}\right) - 0.8\sin\left(18^\circ - \frac{56}{T}\right)\right]$$

$$G = 1.24D;\quad W = 1.24D\cos\frac{180}{T};\quad V = 1.24D\sin\frac{180}{T}$$

$$F = D\left[0.8\cos\left(18^\circ - \frac{56}{T}\right) + 1.24\cos\left(17^\circ - \frac{64}{T}\right) - 1.3025\right] - 0.0015\text{ in.}$$

$$H = \sqrt{F^2 - \left(1.24D - \frac{P}{2}\right)^2}.$$ When $1.24D$ is less than $\frac{P}{2}$, then $H = F$

$$S = \frac{P}{2}\cos\frac{180}{T} + H\sin\frac{180}{T}$$

Outside diameter of sprocket when tooth is pointed

$$= P\cot\frac{180}{T} + 2H$$

Minimum outside diameter of blank $= P\left(0.6 + \cot\frac{180}{T}\right)$

The pressure angle for a new chain is $xab = 35^\circ - \frac{120}{T}$

The minimum pressure angle is $xab - B = 17^\circ - \frac{64}{T}$

The average pressure angle is $26^\circ - \frac{92}{T}$

Standard "Space" Cutters for Sprocket Teeth

Space cutters are made for the following ranges of teeth: 7–8; 9–11; 12–17; 18–34; 35 and over. The lowest number of teeth in any group is designated by n, and the highest by N.

The cutters are based upon an intermediate number of teeth, T, equal to $2Nn \div (N + n)$; but the topping curve zs is based upon N teeth. The values of T for the several cutters are 7.47; 9.9; 14.07; 23.54; and 56.

Space cutters designed for a given roller diameter D will cut sprockets of any pitch.

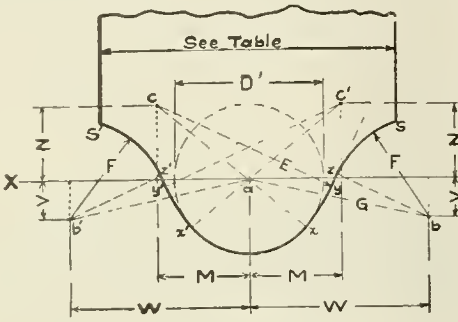

Fig. 3 Space Cutter

Construction. Referring to Fig. 3, draw XY. With a as center and a radius ax equal to $\frac{1}{2} D'$ draw the circular arc for the seating curve xx' (Table 2). Locate c and c' from dimensions M and N (Table 1). With c and c' as centers describe the arcs yx and $x'y'$. Draw yz perpendicular to cy. Locate b from dimensions W and V, draw bz parallel to cy, and with radius bz, equal to F (Table 1), draw the topping curve zs. The line yz is a common tangent to the two circular arcs xy and zs.

Supplementary Data. Tables 1, 2, and 3 give all necessary data for the construction of standard space cutters. Supplementary formulas used in their calculation are given below.

The angle Yab is $180°/T$ when the cutter is made for T teeth only; but it has values as given in Table 3 for cutters covering a range of teeth as here designed. Accordingly the following formulas are special for cutters covering the standard ranges of teeth:

TABLE 1 DATA FOR LAYING OUT CUTTER OUTLINES

Range of teeth	M	N	W	V	F	Chord xy	yz
7–8	$0.585D$	$0.5457D$	$1.1327D$	$0.504D$	$0.7104D - 0.0015''$	$0.2384D + 0.0003''$	$0.039D$
9–11	$0.599D$	$0.5303D$	$1.1782D$	$0.387D$	$0.6981D - 0.0015''$	$0.28D + 0.0003''$	$0.056D$
12–17	$0.619D$	$0.5068D$	$1.2128D$	$0.258D$	$0.6807D - 0.0015''$	$0.3181D + 0.0004''$	$0.090D$
18–34	$0.634D$	$0.4879D$	$1.2353D$	$0.108D$	$0.6542D - 0.0015''$	$0.354D + 0.0004''$	$0.146D$
35 up	$0.647D$	$0.471D$	$1.24D$	0	$0.6345D - 0.0015''$	$0.385D + 0.0004''$	$0.171D$

TABLE 2 SEATING-CURVE DIAMETERS

Roller diam. D, in.	Seating-curve diam. D', in.	Roller diam. D, in.	Seating-curve diam. D', in.
0.200	0.204	3/4	0.757
1/4	0.254	7/8	0.882
0.306 & 4/16	0.317	1	1.008
0.400	0.405	1 1/8	1.134
15/32	0.474	1.55	1.561
9/16	0.568	1 9/16	1.574
5/8	0.631	...	...

TABLE 3 CHECKS

Teeth	E	G	$b-c$ $b'-c'$	$b-c'$ $b'-c$	Angle Yab
7–8	$1.3025D + 0.0015$	$1.24D$	$2.0133D$	$1.1841D$	24°
9–11	$1.3025D + 0.0015$	$1.24D$	$2.0014D$	$1.0847D$	18°10′
12–17	$1.3025D + 0.0015$	$1.24D$	$1.9852D$	$0.9682D$	12°
18–34	$1.3025D + 0.0015$	$1.24D$	$1.9621D$	$0.8465D$	5°
35 up	$1.3025D + 0.0015$	$1.24D$	$1.9445D$	$0.7576D$	0°

$W = 1.24D \cos Ya\,b$; $V = 1.24D \sin Yab$

$$bc' = b'c = \sqrt{(W - M)^2 + (V + N)^2}$$

$$yz = D\left[1.24 \sin\left(17° + \frac{116}{T} - Yab\right) - 0.8 \sin\left(18° - \frac{56}{T}\right)\right]$$

$$F = D\left[0.8 \cos\left(18° - \frac{56}{T}\right) + 1.24 \cos\left(17° + \frac{116}{T} - Yab\right) - 1.3025\right] - 0.0015 \text{ in.}$$

$$cb = c'b' = \sqrt{(E + F)^2 + yz^2}$$

Width of cutter $= 1.02P\left(0.6 + \cot\frac{180}{n}\right)\sin\frac{180}{n}$ to the next higher 32nd inch. Where the same roller diameter is commonly used with chains of two different pitches it is recommended that stock cutters be made wide enough to cut sprockets for both chains.

Design of Standard Straddle Cutters

Only two cutters of this type are required to cover the entire range of teeth.

P = pitch; D = roller diameter; T = number of teeth on which cutter is based.

Construction. Draw XY and the two seating-curve circles as shown in Fig. 4, making radius $ax = 0.5025D + 0.0015$ in.

Locate c and c' from the dimensions K and J as given in Table 4. Locate b and b'. Draw cax and $c'a'x'$ and with centers c and c' draw the "working curves" xy and $x'y'$. Draw yz and $y'z'$ perpendicular to cy and $c'y'$, respectively. Draw bz and $b'z'$ parallel to cy and $c'y'$, respectively. With b and b' as centers and radius equal to bz, strike the arcs of the "topping curves." The dimensions given in Table 4 may be calculated from the formulas given in connection with Fig. 2.

TABLE 4 DATA FOR LAYING OUT STRADDLE-CUTTER OUTLINES

Cutter	To cut	Based on	K	J	F	Chord xy	yz	E	Pressure Angle Avg.	Pressure Angle Max.
B	$17T$ and under	11 Teeth	$0.730D$	$0.327D$	$0.6937D - 0.0005$	$0.2928D + 0.0003$	$0.0617D$	$1.3025D + 0.0015$	17.6°	24.1°
A	$18T$ and over	40 Teeth	$0.678D$	$0.424D$	$0.6596D - 0.0015$	$0.3726D + 0.0004$	$0.1007D$	$1.3025D + 0.0015$	23.7°	32°

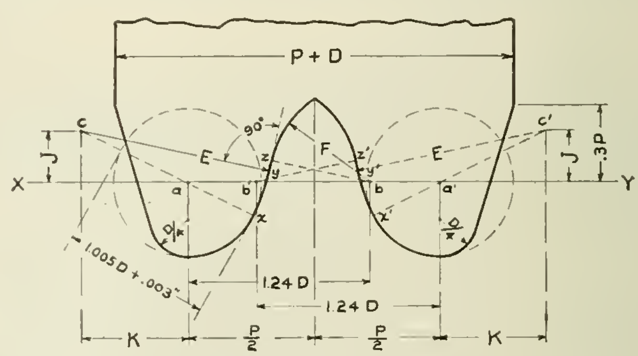

Fig. 4 Straddle Cutter

$$\text{The maximum pressure angle is } xab = 35° - \frac{120}{T}$$

$$\text{The minimum pressure angle is } xab - acy = 17° - \frac{64}{T}$$

$$\text{The average pressure angle is } 26° - \frac{92}{T}$$

Standard Sprocket-Tooth Form for Block Chains

L = pitch of blocks; e = pitch of side plates; P = nominal pitch of chain $= L + e$; D = diameter of round end of block; T = number of teeth.

$$L' = L + 0.005D + 0.003 \text{ in.};\ A = 35° + \frac{120}{T};\ B = 18° - \frac{28}{T}$$

$$ac = 0.8P;\ M = 0.8D \cos\left(35° + \frac{120}{T}\right);$$

$$N = 0.8D \sin\left(35° + \frac{120}{T}\right)$$

$$E = 1.3025D + 0.0015 \text{ in.}$$

$$\text{Chord } xy = 2.6D \sin\left(9° - \frac{14}{T}\right)$$

$$yz = D\left[1.24 \sin\left(17° - \frac{32}{T}\right) - 0.8 \sin\left(18° - \frac{28}{T}\right)\right]$$

$$G = 1.24D;\; W = 1.24D \cos\frac{180}{T};\; V = 1.24D \sin\frac{180}{T}$$

$$F = D\left[0.8 \cos\left(18° - \frac{28}{T}\right) + 1.24 \cos\left(17° - \frac{32}{T}\right) - 1.3\right]$$

$$H = \sqrt{F^2 - \left(1.24D - \frac{P - L'}{2}\right)^2}, \text{ very nearly,}$$

$$S = H \sin\frac{180}{T} + \frac{P - L'}{2}\cos\frac{180}{T} + \frac{L'}{2}, \text{ very nearly.}$$

Outside diameter of sprocket when tooth is pointed =

$$2H + \frac{L' + (P - L')\cos\dfrac{180}{T}}{\sin\dfrac{180}{T}}, \text{ very nearly.}$$

$$\text{Minimum outside diameter of blank} = 0.6e + \frac{L + e\cos\dfrac{180}{T}}{\sin\dfrac{180}{T}}$$

The pressure angle for a new chain is $xab = 35° - \dfrac{60}{T}$

The minimum pressure angle is $xab - B = 17° - \dfrac{32}{T}$

The average pressure angle is $26° - \dfrac{46}{T}$

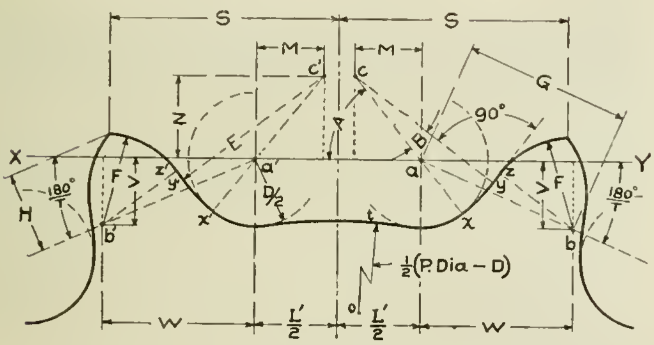

Fig. 5 Tooth Form for Block Chains

Standard Cutters for Block-Chain Sprockets

Sprocket cutters for block and twin-roller chains are made for the same ranges of teeth as for roller-chain sprockets and are based upon the same number of teeth.

Construction. Referring to Fig. 6, draw XY. Locate a and a' making L' = pitch of block + $0.005D$ + 0.003 in., and with these points as centers (radius = $\frac{1}{2}D$) draw the circular arcs for the seating curves. With radius ot, equal to one-half the bottom diameter of the largest sprocket to be cut, draw an arc tangent to the two seating curves. Locate c and c' from dimensions M and N (Table 5). With c and c' as centers describe the arcs xy and $x'y'$. Draw yz and $y'z'$ perpendicular to cy and $c'y'$, respectively.

TABLE 5 DATA FOR LAYING OUT BLOCK-CUTTER OUTLINE

Range of teeth	M	N	W	V	F	Chord xy	yz	ol	Q
6	0.4589D	0.6554D	1.0738D	0.620D	0.6927D	0.3019D	0.0662D	0.97P−0.5D	1.12P
7–8	0.5027D	0.6223D	1.1327D	0.504D	0.6845D	0.3227D	0.0779D	1.28P−0.5D	1.12P
9–11	0.5318D	0.5950D	1.1782D	0.387D	0.6764D	0.3432D	0.0861D	1.76P−0.5D	1.11P
12–17	0.5801D	0.5510D	1.2128D	0.258D	0.6638D	0.3622D	0.1111D	2.71P−0.5D	1.10P
18–34	0.6120D	0.5152D	1.2353D	0.108D	0.6431D	0.3801D	0.1577D	5.41P−0.5D	1.08P
35 up	0.6403D	0.4796D	1.24D	0	0.6308D	0.3955D	0.1763D	∞	1.05P

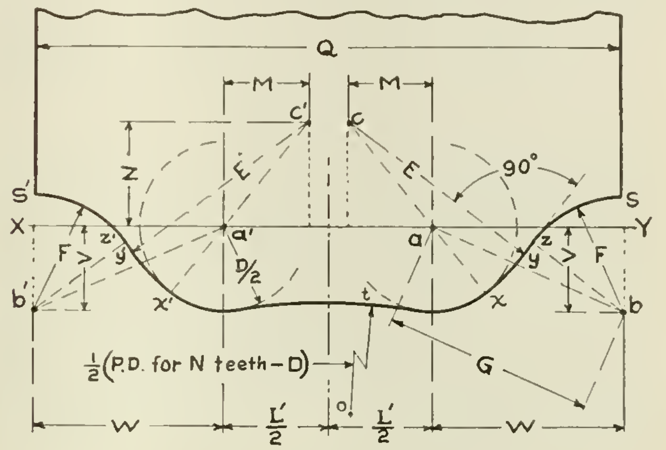

Fig. 6 Block Cutter

Locate b and b' from dimensions W and V. With these as centers and a radius F, draw the arcs ZS and $Z'S'$. The line yz is a common tangent to the curves xy and zs.

Supplementary Data. Formulas used in the calculations of data in Tables 6 and 7 are given below.

The angle Yab is $180°/T$ when the cutter is made for T teeth only, but it has values as given in Table 6 for cutters covering a range of teeth as here designed. Accordingly the following formu-

(Continued on page 511)

TABLE 6 CHECKS

Range of teeth	E	G	Angle Yab
6	1.3D	1.24D	30°
7–8	1.3D	1.24D	24°
9–11	1.3D	1.24D	18°10′
12–17	1.3D	1.24D	12°
18–34	1.3D	1.24D	5°
35 up	1.3D	1.24D	0°

TABLE 7 RECOMMENDED SIZES OF CUTTERS FOR BLOCK-CHAIN SPROCKETS

Pitch of Chain	Block End Diam., in.	Pitch of Block, in.	Cutter Diam., in.	Bore, in.	Keyway, in.	Cutter Width 6T	7–8T	9–11T	12–17T	18–34T	35T up
1	0.325	0.400	3	1	5/32 × 5/64	1 3/16	1 5/32	1 5/32	1 1/8	1 1/8	1 3/32
1 1/2	0.531	0.563	4	1 1/4	3/16 × 3/32	1 25/32	1 3/4	1 3/4	1 11/16	1 11/16	1 5/8

TABLE 8 RECOMMENDED SPROCKET-CUTTER SIZES

Pitch, in.	Roll Diam., in.	Cutter diameter (min.), in. 6T	7–8T	9–11T	12–17T	18–34T	35T and over	Cutter width (min.), in. 6T	7–8T	9–11T	12–17T	18–34T	35T and over	Bore	Keyway
*3/8	0.200	2 3/4	2 3/4	2 3/4	2 3/4	2 3/4	2 3/4	15/32	15/32	15/32	7/16	7/16	13/32	1	5/32 × 5/64
3/8	0.250	2 7/8	2 7/8	2 7/8	2 7/8	2 7/8	2 7/8	15/32	15/32	15/32	7/16	7/16	13/32	1	5/32 × 5/64
3/8 to 1/2	0.250	2 3/4	2 7/8	2 7/8	2 7/8	2 7/8	2 7/8	5/8	5/8	19/32	19/32	9/16	9/16	1	5/32 × 5/64
1/2	0.313	2 7/8	3	3	3	3	3	5/8	5/8	19/32	19/32	9/16	9/16	1	5/32 × 5/64
*1/2 to 5/8	0.313	3	3	3 1/8	3 1/8	3 1/8	3 1/8	3/4	3/4	3/4	3/4	23/32	11/16	1	5/32 × 5/64
*5/8	0.400	3 1/8	3 1/8	3 1/4	3 1/4	3 1/4	3 1/4	3/4	3/4	3/4	3/4	23/32	11/16	1	5/32 × 5/64
5/8 to 3/4	0.400	3 1/4	3 1/4	3 3/8	3 3/8	3 3/8	3 3/8	29/32	29/32	28/32	7/8	27/32	13/16	1	5/32 × 5/64
*3/4	0.469	3 1/4	3 1/4	3 3/8	3 3/8	3 3/8	3 3/8	28/32	29/32	28/32	7/8	27/32	13/16	1	5/32 × 5/64
3/4 to 1	0.469	3 1/4	3 3/8	3 3/8	3 1/2	3 1/2	3 1/	1 1/4	1 1/4	1 3/16	1 5/16	1 1/8	1 3/32	1	5/32 × 5/64
*1	0.563	3 3/4	3 7/8	3 7/8	4	4	4	1 1/4	1 1/4	1 3/16	1 3/32	1 1/8	1 3/32	1 1/4	3/16 × 3/32
1	0.625	3 7/8	4	4	4 1/8	4 1/8	4 1/8	1 1/4	1 1/4	1 3/16	1 5/32	1 1/8	1 3/32	1 1/4	3/16 × 3/32
*1 to 1 1/4	0.625	3 7/8	4	4 1/8	4 1/8	4 1/4	4 1/4	1 1/2	1 1/2	1 15/32	1 15/32	1 13/32	1 11/32	1 1/4	3/16 × 3/32
1 1/4	0.750	4	4 1/8	4 1/4	4 1/4	4 3/8	4 3/8	1 1/2	1 1/2	1 15/32	1 15/32	1 13/32	1 11/32	1 1/4	3/16 × 3/32
*1 1/4 to 1 1/2	0.750	4 1/4	4 3/8	4 1/2	4 1/2	4 5/8	4 5/8	1 13/16	1 13/16	1 25/32	1 3/4	1 11/16	1 5/8	1 1/4	3/16 × 3/32
*1 1/2	0.875	4 3/4	4 7/8	5	5	5 1/8	5 1/8	1 13/16	1 13/16	1 25/32	1 3/4	1 11/16	1 5/8	1 1/2	5/16 × 3/32
1 1/2 to 1 3/4	0.875	4 7/8	5	5 1/8	5 1/4	5 3/8	5 3/8	2 3/32	2 3/32	2 1/16	2 1/32	1 31/32	1 7/8	1 1/2	5/16 × 5/32
*1 3/4	1.000	5	5 1/8	5 1/4	5 3/8	5 1/2	5 1/2	2 3/32	2 3/32	2 1/16	2 1/32	1 31/32	1 7/8	1 1/2	5/16 × 3/32
1 3/4 to 2	1.000	5 1/8	5 1/4	5 3/8	5 1/2	5 5/8	5 5/8	2 13/32	2 13/32	2 3/8	2 5/16	2 1/4	2 5/32	1 1/2	5/16 × 5/32
*2	1.125	5 3/8	5 1/2	5 5/8	5 3/4	5 7/8	5 7/8	2 13/32	2 13/32	2 3/8	2 5/16	2 1/4	2 5/32	1 1/2	5/16 × 3/32
2 to 2½	1.125	5 1/2	5 3/4	5 7/8	6	6 1/8	6 1/4	3	3	2 15/16	2 29/32	2 3/4	2 11/16	1 1/2	5/16 × 5/32
*2 1/2	1.550	6 3/8	6 5/8	6 3/4	6 7/8	7	7 1/8	3	3	2 15/16	2 29/32	2 3/4	2 11/16	1 3/4	3/8 × 3/16
2 1/2 to 3	1.550	6 3/4	7	7 1/8	7 1/4	7 1/4	7 1/2	3 19/32	3 19/32	3 17/32	3 15/32	3 11/32	3 7/32	1 3/4	3/8 × 3/16
*3	1.900	7 1/2	7 3/4	7 7/8	8	8	8 1/4	3 19/32	3 19/32	3 17/32	3 15/32	3 11/32	3 7/32	2	1/2 × 1/4

* Cutter will fill all requirements for chains as made in the United States at the present time.

ENGINEERING RESEARCH

A Department Conducted by the Research Committee of the A.S.M.E.

Résumé of the Month

A—Research Results

The purpose of this section of Engineering Research is to give the origin of research information which has been completed, to give a résumé of research results with formulas or curves where such may be readily given, and to report results of non-extensive researches which in the opinion of the investigators do not warrant a paper.

Aeronautics A2-23. Aeronautic Instruments. This paper describes in detail various aeronautic instruments and will be useful to those interested in the general aspects of the aeronautic-instrument art. It was prepared by F. L. Hunt and is known as Bureau of Standards Technologic Paper No. 237. For a copy address Superintendent of Documents, Washington, D. C.; price, 20 cents.

Building Materials A2-23. Loading Test of a Hollow-Tile and Reinforced-Concrete Floors. The Arlington Building, Washington, D. C. was originally intended for a hotel with a live load of 75 lb. per sq. ft. On account of the purchase by the Government for other uses, the construction was strengthened in view of possible loads on floor panels of 100 lb. per sq. ft. The width of the panels of this building varied from about 11 to 15 ft. and the ratio of length to width varied from 1 to 2.

A 1 : 2 : 4 gravel concrete was used; that in the columns and beam stems was very "sloppy;" in the slabs it was somewhat drier. Tests on the cylindrical specimens and the difficulty of chipping the slabs in the preparation for the test showed the concrete to be of good quality. The age of the specimens was about two and one-half months. Round and square smooth bars and square corrugated bars were used for reinforcement. The tiles used in the floors appeared to be of medium-burned grade, except some of the 4-inch tiles, which apparently were hard-burned. The columns consist of a steel H-section surrounded by a thick casing of concrete, the total column being 16 in. square. Vertical rods for reinforcement were placed at each corner and held in place by square ties made of 1/4-in. round rods placed 12 in. on centers and 2 in. from the surface of the concrete, which were designed to prevent spalling in case of fire.

This type of construction was new in many respects and the structure is considerably lighter than recommended by the final report (1916) of the Joint Committee on Concrete and Reinforced Concrete or allowed by most building codes. The primary purpose of the test was, therefore, to find how much live load could actually be placed on individual panels before serious stresses were developed. It was desired by all concerned in this test to secure as much information as possible on the action of the hollow-tile slabs and incidentally also on the framework when subjected to load.

The tests herein described are among the first to be made on this type of construction, which is a framework of light-weight structural-steel members used as reinforcement for the concrete columns and beams, supporting two-way reinforced concrete and terra-cotta, hollow-tile floor panels.

The authors of this Bureau of Standards Technologic Paper No. 236 are Messrs. L. J. Larson and S. N. Petrenko. The paper includes a bibliography of 29 items describing similar field tests of floors in reinforced-concrete buildings. Address Superintendent of Documents, Washington, D. C. Price, 15 cents.

Fuels A5-23. Combustion of Powdered Coal. This paper contains a review of some tests conducted by the U. S. Bureau of Mines and the Combustion Engineering Corporation on boilers fired with powdered coal, which show that coal when powdered may be burned with greater thermal efficiency for steam raising than when burned in any other way. It was presented before the section of Gas and Fuel Chemistry at the 64th meeting of the American Chemical Society, Pittsburgh, Pa. by Henry Kreisinger, Research Engineer, Combustion Engineering Corporation, and John Blizard, Fuel Engineer of the U. S. Bureau of Mines. Address H. Foster Bain, Director, U. S. Bureau of Mines, Washington, D. C. requesting copy of Serial No. 2470.

Lubricants A2-23. Physical and Chemical Properties of Lubricating Oils Made from California Crudes. This is the second of a series of reports on a survey of petroleum products manufactured on the Pacific Coast from California crude oils. California crudes differ in many characteristics from the petroleum produced in other parts of the United States, and the claim has been made that some of the present Federal Specifications for petroleum products tend to discriminate against California products. The purposes of the present survey are to determine what particular specification requirements California petroleum products characteristically fail to meet, how widely the products deviate from these requirements, and if possible to show whether the fault lies with the specifications or the products, or along what lines investigation to determine the question should proceed. The first report of the series gave the physical and chemical properties of gasoline and mineral spirits made from California crudes.

Data on the physical and chemical properties of the samples tested are given in tables, each of which is preceded by the classification and specifications for the particular class of oil considered. Following each table brief notes show wherein samples deviate from specification requirements.

Most of the oils meet the specification requirements as regards flash point, viscosity, pour point; corrosion and reaction tests, except for deviations which for the most part are of minor importance.

Those desiring full information concerning these tests should address the authors, Messrs. E. C. Lane and N. F. LeJeune at the Bureau of Mines, Washington, D. C., requesting a copy of Serial No. 2482.

Mining A1-23. Monel Metal a Material for Flame Safety Lamp Gauzes. This pamphlet known as Serial No. 2468 of the Bureau of Mines was prepared by Messrs. A. B. Hooker and R. A. Kearns.

Monel metal, the natural alloy of nickel and copper, is practically noncorrodible. Its melting point is approximately the same as that of steel. From time to time it has been suggested that this alloy might be a better gauze material than steel, and the investigation showed that it is a very satisfactory material for the purpose.

Monel-metal gauzes maintained their shape and stiffness under the greatest heat to which they were subjected in gaseous mixtures equally as well as steel gauzes did; this together with the fact they do not corrode perceptibly in humid atmospheres should assure a much longer life for Monel-metal gauzes. For copies address H. Foster Bain, Director, U. S. Bureau of Mines, Washington, D. C.

Non-Ferrous Metals A5-23. Monel-Metal a Material for Flame Safety Lamp Gauzes. See *Mining A1-23.*

Properties of Engineering Materials A1-23. Loading Test of a Hollow-Tile and Reinforced-Concrete Floors. See *Building Materials A2-23.*

Refrigeration A2-23. New Mollier Chart for Ammonia. In reference "Refrigeration A2-23" (July issue of Mechanical Engineering) the publication of Tables of Thermodynamic Properties of Ammonia was announced. These data are now available in the form of a Mollier chart.

Pressures and volumes can easily be read on this chart with an accuracy of 1 per cent and heat content to within 0.5 B.t.u. It may be used as a complete substitute for the tables in calculations which do not require the highest degree of accuracy and such computations can be carried out by this means with much greater speed than is possible from data presented in tabular form.

It is known as Bureau of Standards Miscellaneous Publication No. 52, and can be obtained from the Superintendent of Documents, Washington, D. C., at 5 cents per copy.

Safety Devices A1-23. Monel Metal a Material for Flame Safety Lamp Gauzes. See *Mining A1-23.*

B—Research in Progress

The purpose of this section of Engineering Research is to bring together those who are working on the same problem for coöperation or conference, to prevent unnecessary duplication of work, and to inform the profession of the investigators who are engaged upon research problems. The addresses of these investigators are given for the purpose of correspondence.

Automotive Vehicles and Equipment B1-23. Growth of Cast-Iron Pistons. See *Iron and Steel B2-23.*

Building Materials B2-23. Colorless Waterproofing Materials for Stone. Investigations are now under way at the Bureau of Standards covering the action of frost on building stone and on the value of colorless waterproofing materials with which to protect the surface of stone structures. During the last month the series of exposure tests on such materials, having for its object the determination of the relative durability of these treatments under weather conditions, has been supplemented by a series of tests to determine the efficiency of the different waterproofing materials in preventing decay of the stone.

Crystallization tests are being made on waterproofed specimens of stone to secure a comparison between treated and untreated specimens. Waterproofed specimens have also been exposed to the weather and will be tested after a considerable period of exposure.

Electrolysis B1-23. Efects of Impurities in Storage-Battery Electrolytes. The importance of obtaining information concerning the action of impurities in storage-battery electrolytes arises from the detrimental effects which many of them produce on the operating characteristics and life of the storage battery. Such information is necessary as a basis for the preparation of specifications covering sulphuric acid for use in batteries. In the present investigation the effects of small

amounts of iron, manganese, platinum, and copper have been determined. It was found that the presence of 1 part in 10,000,000 of platinum in the electrolyte increases the local action at the negative plates 50 per cent; the effect of copper is much less, while the effect of iron is of unusual interest because of its accelerating action at the negative plates. Manganese deposits upon the positive plates in the form of manganese dioxide which covers the active material, closes the pores, and causes a large amount of charging current to be wasted as gas. Work is being extended which will include the effect of other impurities.

Hardness B1-23. Study of Quenching Media. The object of a new investigation started by the Bureau of Standards during the past month is to obtain more complete information than is now available on the cooling properties of the ordinary quenching liquids used in the heat treatment of steel. It is also hoped that some information bearing on the subject of dimensional changes, occurring during the hardening of steel, will also be obtained. A few preliminary experiments have been carried out in quenching nickel cylinders in water with very satisfactory results. As the preliminary work is now practically completed, it is hoped that considerable progress will be made on the main investigation during the next few weeks.

Iron and Steel B2-23. Growth of Cast-Iron Pistons. This research has been conducted with special reference to the growth of the cast iron used in automobile pistons. While it has been known for years that pistons can be grown a very small amount, this investigation has shown that this amount can be made many times greater under the proper treatment, and as such developed to the point where it can be used as a certain and practical repair process.

Further work remains to be done on this subject which may be done very profitably: (1) The determination of the variation of the constituents in the material with the number of treatments, the temperature used, etc. (2) The variation of the strength under the same conditions. (3) The more complete control of warp. (4) The extent, the location and magnitude of internal strains. (5) The variation of hardness of the pistons before and after different heat treatment. This investigation has been conducted by A. R. Nottingham, State College of Washington, Pullman, Washington.

Mining B1-23. Non-Destructive Testing of Wire Rope. See *Properties of Engineering Materials B1-23.*

Non-Ferrous Metals B3-23. Scratch Hardness of Copper. The results obtained in cold rolling very pure, electrolytic, unmelted copper and also ordinary commercial copper indicate clearly that the early stages of the deformation of the metal harden it very rapidly. The maximum degree of hardness is soon reached, however, and a reversal occurs, the metal becoming very appreciably softer as the deformation process is continued, so that the metal in its final condition after cold rolling is completed, is softer as measured by the scratch hardness method than in its initial state. These results are confirmed by tests made on the same material by the micro-Brinell method. Annealing cold-rolled sheets at a low temperature (100 deg. cent.) softens the material appreciably, but the general form of the hardness deformation curve is not affected.

After annealing at a higher temperature all specimens showed the same hardness, thus indicating that thinness of the rolled material does not affect materially the results of the scratch hardness test. This is an important point and suggests the use of this method of hardness testing on such specimens as are too thin to permit the determination of hardness by other more familiar methods. The results which were obtained with pure iron and with an iron-carbon alloy (low-carbon) were of the same general character as those obtained with copper and thus helped to confirm the conclusions which had been tentatively reached.

This work which is being carried on by the Bureau of Standards will be extended to a few other metals to determine whether this behavior is peculiar to copper or more general in its nature.

Properties of Engineering Materials B1-23. Non-Destructive Testing of Wire Rope. An investigation of the possibilities of using non-destructive methods for testing wire rope with special reference to hoisting rope is about to be undertaken by the Bureau of Standards. Present methods of inspection are unsatisfactory and do not unfailingly tell when it is necessary to remove the rope from service. The object of this investigation is to develop, if possible, some method by which an actual test can be made to determine the conditions of the rope with respect to its deterioration in service, without destroying it. An advisory committee is being organized which will be composed of representatives of the principal interests connected with the manufacture, use, and testing of wire rope.

Steel—Its Treatment and Products B2-23. Heat Treatment and Properties of Magnet Steels. The Metallurgical and Electrical Divisions of the Bureau of Standards in coöperation, are beginning an investigation to determine the effects of various heat treatments upon the characteristic properties of the steels now used commercially or suggested for use in the manufacture of permanent magnets. During the past month about 10 samples were hardened, and it is hoped that they will soon be ready for the first magnetic tests.

Safety Devices B1-23. Non-Destructive Testing of Wire Rope. See *Properties of Engineering Materials B1-23.*

A.S.M.E. Boiler Code Committee Work

The Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society, for approval, after which it is issued to the inquirer and simultaneously published in Mechanical Engineering.

Below are given the interpretations of the Committee in Cases Nos. 414, 416 and 418, as formulated at the meeting of April 26, 1923, and Cases Nos. 419 and 420 as formulated at the meeting of May 31, 1923, and approved by the Council. In accordance with the Committee's practice, the names of inquirers have been omitted.

Case No. 414

Inquiry: Is it permissible, in the case of the flue of an internally-fired boiler which is corrugated for about half of its length and the remainder plain, to calculate the thickness of the plain portion in accordance with Par. 239, assuming that the length of the plain portion is the distance from the center line of the rivets in the head to the beginning of the corrugations?

Reply: It is the opinion of the Committee that in the calculation of the thickness of the plain portion of such a furnace, Par. 239*b* should be used, taking for the length the distance from the face of the flange to the center of the first definite corrugation, and the thickness thus obtained shall be uniform throughout the entire length of the flue.

Case No. 416

(In the hands of the Committee)

Case No. 418

Inquiry: Is it permissible under the requirements of the Heating Boiler Section of the Code, to attach the safety valve to the pipe-header outlet connection of a type of cast-iron sectional heating boiler with sections designed too narrow to admit of a separate opening on any one of them for the safety valve?

Reply: If the design of the boiler is such that it is not possible to form the safety-valve openings directly on the boiler sections, it is the opinion of the Committee that the sections should be connected at two or more points to a manifold or header which will serve as a steam drum, and that it will be permissible to mount the safety valve on this manifold or header.

Case No. 419

(In the hands of the Committee)

Case No. 420

Inquiry: Is it permissible, under the requirements of the Boiler Code, to drive up a blister or blisters on a tube or tubes of a water-tube boiler and reinforce them by depositing metal over the same by the autogenous process; or later when other blisters appear above or below the first reinforcement to again use the same process, increasing the length of the reinforcement; also to weld tubes lengthwise by the same process regardless of minimum or maximum length of weld for any thickness of tube and for any pressure without removing the tube from boiler or annealing the welding?

Reply: It is the opinion of the Committee that such reinforcement or welding of blisters or other defects in the tubes of water-tube boilers would be analogous to the welding of cracks in shell plates subject to tensile strain which is prohibited under the Recommendations for Repairs by Welding in the Appendix of the 1918 Edition of the Code, page 127, third paragraph.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

The American Society of Mechanical Engineers

29 West 39th Street, New York

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An American Screw-Thread Series

Luther D. Burlingame

It might be assumed because we have the long-established U. S. Standard for Screw Threads, and for small diameters the more recently adopted A.S.M.E. Standard, also the S.A.E. Standard for fine threads, that all the requirements for American Screw-Thread Standardization have been met. The problem of interchangeability, however, is only partly solved by the establishment of the general form of thread, and of the relation of pitch to diameter. That this is so is shown by the wide variation in screw and nut products now on the market, also of taps and dies. In spite of the degree of standardization so far attained, the screw-thread product of one manufacturer often will not interchange with that of another, because each of them is working within his own range of limits and tolerances.

The requirements of the Navy will illustrate the need of further steps in standardization. The importance of naval vessels' being able to secure from a wide variety of sources necessary supplies involving questions of screw threads is apparent, and yet at the present time interchangeability in such products cannot be assured even when they are manufactured ostensibly according to the same system.

It is to remedy this condition that further efforts at standardization have been undertaken.

As far back as 1912 the A.S.M.E. appointed a Committee on Limits and Tolerances in Screw-Thread Fits. This Committee after a number of years' work rendered a report which will be found in the A.S.M.E. Transactions, Vol. 42, page 1053, and which laid the foundation for further progress.

Members of this original Committee, recognizing that the whole screw-thread problem was too great to solve at a single effort and with limited support, took steps to secure Government coöperation, and through their influence a commission was appointed by the U. S. Government to make a thorough study of the whole matter.

The able and thorough work of this commission resulted in the publication in 1921 of the Progress Report of the National Screw Thread Commission, covering coarse and fine systems of screw threads for general use, pipe threads, hose-coupling threads, and also gaging systems, such as to insure the products' coming within the required tolerances for the classes of work for which each was intended.

This report was officially brought to the attention of the two engineering societies having the most vital interest in its findings, and they (the S.A.E. and the A.S.M.E.) were made sponsors, under the procedure of the A.E.S.C., for the purpose of reviewing the Report of the Commission.

The work of the joint committee appointed under this authorization has been done with the special purpose of adapting the report of the commission to the practical and everyday uses of industry. For that reason its work has been largely a "boiling down" and rearranging process, and the suggesting of such modifications as would make the original report more workable.

Two years of effort, including painstaking committee and subcommittee work and conferences with the National Screw-Thread Commission, have resulted in bringing about full agreement with the commission regarding suggested changes, and the Joint Committee now presents its first Report, several sections of which will be found on page 498 of this issue of Mechanical Engineering.

The question of gaging has not been made a part of this first Report but will take the form of a later one, the subject being treated so as to lay down general principles rather than to recommend the adoption of a particular plan of gaging, as it is felt that the primary purpose is to establish the requirements of interchangeability for the product and leave to each manufacturer the determining of methods to bring it within those requirements.

While the standard here submitted represents distinctly an American standard and is the outgrowth of American practice, there is still a hope on the part of the committee that it will prove a steppingstone toward uniformity with British standards. This possibility has been in the minds of both the commission and the joint committee, resulting in incorporating in the Report such features as would most nearly accord with and aid in interchangeability with the Whitworth Standard. Study has also been given to the question as to what mutual concessions might be practicable so as to eventually bring the two systems of the English-speaking world into uniformity.

The "ice was broken" at the time of the National Screw-Thread Commission's visit to England, in 1919, when the question of the desirability and practicability of unifying the two systems was frankly discussed. The fact that they are so nearly alike as to be in most cases capable of "emergency interchangeability" gives hope for eventually bringing them together.

At the recent Montreal Meeting of the A.S.M.E. a further conference was held between the members of the joint committee and the Canadian Engineering Standards Association, and through the good offices of the latter the matter is now being further discussed with the British Engineering Standards Association in London.

If such conferences should result in bringing about uniformity in screw-thread products throughout the English-speaking world it would be a great achievement and one worthy of mutual concessions for its attainment.

Pending such further negotiations and the final approval of the sponsor bodies it is thought best to make this report now available for use.

Luther D. Burlingame.[1]

Formulas for Computing Economies of Labor-Saving Equipment

The publication of the report of the Formula Committee, of the A.S.M.E. Materials Handling Division, which was presented at the Spring Meeting of the Society held in Montreal, Canada, May 28–31, 1923, has been deferred to a later issue of Mechanical Engineering.

[1] Indus. Supt. Brown and Sharpe Mfg., Co., Providence, R. I. Chairman of Sectional Committee on Standardization and Unification of Screw Threads.

John R. Freeman Recommended for A.S.M.E. Medal for 1923

THE A.S.M.E. Committee on Awards and Prizes has recommended to the Council that the Society Medal for some notable invention or striking improvement in connection with the industries be awarded[1] for the year 1923 to Past-President John R. Freeman for his eminent service to engineering and manufacturing by his meritorious work in fire prevention and the preservation of property. The following is a brief statement of his activities in the development of the system of rules and inspection under the Factory Mutual Insurance Companies, which have saved the industries millions of dollars.

Mr. Freeman became associated with the Factory Mutual Insurance Companies in 1886 when they were small and their membership was confined mainly to New England factories. Immunity from loss was dependent mainly upon careful management and oversight rather than upon appliances for extinguishing fire. One of his earliest activities was the conducting of a series of experiments on fire streams, during which the friction loss of water flowing through various kinds of hose was determined and the most efficient shape for nozzles developed. The results of these tests, made at Lawrence in 1888, were later tabulated and published as the Fire Stream Tables. These tables are the standard used by all engineers having to do with the flow of water through nozzles or hydrants.

Harris and Ewing

John R. Freeman

Next Mr. Freeman made a study of reciprocating duplex pumps and developed the designs for the Underwriters' steam fire pump. Later on the details of rotary fire pumps were improved and standardized.

The automatic sprinkler was being developed in the latter '80's and early '90's, but there was no uniformity in the practice of spacing heads or arranging pipes. In 1892 Mr. Freeman conducted an elaborate series of experiments on sprinklers to determine the effective area of water distribution, and also a series of tests on the flow of water through pipes. Much valuable information was obtained on the friction loss in all sizes of pipes from $^3/_4$ in. to 8 in., together with the fittings, which was used as the basis for the present regulations for sprinkler spacing and supplies.

About the same time Mr. Freeman became interested in the improvement of construction of mills and worked out many of the details of the so-called New England mill-construction type of buildings. The construction of storehouses was studied and many typical structures were devised and adopted by the members. Some of the earliest buildings with the saw-tooth type of roof construction were designed in accordance with his views.

The first comprehensive set of electrical rules was compiled under Mr. Freeman's direction.

Mr. Freeman was placed in charge of the inspection department of the companies in January, 1890, and reorganized it along more efficient lines. He arranged for regular inspection service, systematic surveys and plans of risks, a laboratory for testing and research, and a division for adjustments and appraisals, as well as experts in special lines, such as mill construction, electricity, and chemistry. Tests were made on meters to determine the friction loss and a full flow meter designed that would be fairly accurate yet was free from the danger of becoming obstructed. Dry-pipe valves were developed in order to have automatic protective equipments in cold rooms. "Germ-proof" check valves were designed to prevent possibly polluted water being forced back into public mains.

In the early days of his connection with the inspection department there were a number of losses due to closed valves. All valves were underground; some turned to the right to open, others turned to the left, and there was no certainty as to the condition of the valve unless water was flowing. Mr. Freeman devised the so-called indicator post valve with its extension stem and target above ground to show clearly the condition of the valve. He was also responsible for the development the outside screw-and-yoke type of valve for inside piping.

All of the various features of the construction and protection of factories were studied intensively under Mr. Freeman's direction, and many safeguards were devised which proved a benefit not only to the manufacturers but also to the merchants and the public in general.

W. M. McFarland, *Chairman,*
Committee on Awards and Prizes.

[1] Appendices to the Rules: In no case will this award be made until the invention or improvement shall have been fully described in Mechanical Engineering for a period of thirty days.

A.S.M.E. Council Urges Prompt Trial of Indicted Engineers

AT a meeting of the Council of the A.S.M.E. held in Montreal, May 29, 1923, the following resolutions were passed in reference to the Department of Justice cantonment indictments and suits.

Whereas, the Council of The American Society of Mechanical Engineers, having an organization of approximately 16,000 members, has been shocked by the indictment of certain of the prominent members of the engineering profession on charges of conspiracy amounting to treason in time of war, and by the bringing of civil suits for many millions of dollars against some of the most reputable contracting organizations in the country, some members of which are honored members of the engineering profession, for alleged fraud in connection with the construction of the cantonments; and

Whereas, in the documents under which these actions were brought, it is stated that the findings of the Presidents of three National Engineering Societies and other members of the Committee appointed to pass on the contract adopted by the Emergency Construction Committee were not the result of investigation but of unconsidered substantiation of the actions of the Emergency Construction Committee; and

Whereas, in the text of the documents those indicted and those sued are repeatedly accused of delaying the Government's program of construction for the cantonments, while those who are well informed know that this work was done at an extraordinary speed; and

Whereas, wide publicity was given to those suits at the time they were brought, but now the officials of the Department of Justice are showing a disposition to delay in trying those actions; and

Whereas, the Constitution of the United States guarantees to every accused citizen a speedy trial.

Therefore, be it Resolved: That the Department of Justice, having challenged the integrity and honesty of purpose of prominent men in the engineering profession through these actions, the Council of this Society urge the prompt trial of these charges. Also that it is the duty of every member of this Society to demand through every avenue available that these charges be promptly tried.

And be it Further Resolved: That copies of this resolution be sent to the President of the United States and the Attorney General, and be printed in Mechanical Engineering.

The actions in question were begun in November, December, and January. Indictments were secured against seven former Government administrative officials and agents as follows: Benedict Crowell, Cleveland, former Assistant Secretary of War; W. A. Starrett, New York, contractor; M. C. Tuttle, Boston, contractor; C. W. Lundoff, Cleveland, contractor; C. Foster, Major in the Engineer Corps during the war, engineer in construction business; J. H. MacGibbons, Chicago, representative of a bonding company; and J. A. Means, New York, contractor. These men, members of the Emergency Construction Committee during the war, are accused of frauds in contracts for erection of cantonments, port terminals, warehouses, and fortifications.

The firms against which suits on similar charges, totalling fifteen million dollars, were brought include many members of the engineering profession.

Similar resolutions were adopted by the Associated General Contractors of America, at their Annual Meeting, Feb. 2, 1923.

Objects and Methods of the F.A.E.S. Committee on Coal Storage

THE FEDERATED AMERICAN ENGINEERING SOCIETIES has undertaken the study of coal storage for certain distinct reasons. The main one is that in the extended and somewhat involved discussion on this subject, participated in by several Federal bureaus and Congressional committees, there has arisen a real need for an unbiased report on what is being done and what might be done in the storage of coal for the nation at large. The engineer is by nature the man who can meet this test. What we desire to secure are the facts pertaining to this important question.

In fulfilling this object the first step is to assemble the results of all investigations which have been made. A great deal of scientific work has been done, the reports on which are scattered through public reports. These are to be compiled so that the final report will contain authoritative statements as to the conditions under which coal may be stored. It is believed that such a compilation will serve a distinct purpose. We are fortunate in having on the committee Mr. S. W. Parr, professor of industrial chemistry at the University of Illinois, one of the leading authorities on the chemistry of coal.

One of the immediate functions of this committee is that of securing information for the use of the United States Coal Commission. This means that this work is closely associated with that of the Coal Commission and the Federal fuel distributor in the Department of Commerce. Information will be made available showing the coal requirements of various important industrial districts and of important groups of industries.

Closely associated with the phase of the work last mentioned, is the need expressed by the War Department for information on the fuel requirements of various manufacturing concerns which might supply munitions in case of war emergency. While this is incidental to the main work of the committee, it is expected that information of value may be derived.

It is evident to all that the leading motive prompting the investigation is that of determining the conditions under which storage might affect production in bituminous coal mining fields. For several reasons it is desirable that coal mining operations be stimulated in the Spring and Summer in order to cut down the intensity of demand upon the mines during the Fall and Winter season. The bituminous mines are operating only part time during warm weather, while the rush of orders at other seasons of the year necessitate the maintenance of a force of miners and of producing equipment capable of a peak-load production higher than is necessary. A primary object is to reduce this peak load, and create a more uniform demand throughout the year.

While it is not within the scope of the engineering investigation to initiate the measures to bring about a change, it is distinctly the purpose to furnish the information on which such efforts might be initiated by the proper parties.

It might be said that, in addition to the analysis of conditions under which coal may be stored, one of the most important portions of the work will be to determine the actual cost of storage. In order that industries and Governmental agencies may decide whether storage may be undertaken, it is necessary to know just what it costs.

It is not to be expected, of course, that coal will be stored unless users realize a financial advantage from doing it. To secure this information the combined experiences of all of the concerns which have stored coal are being sought. When such data have been accumulated, and conditions at the more notable coal storage plants have been studied, it is intended to develop typical statements as to the possibilities and suggestions for the best methods which might be employed in storage.

These in brief are the primary objects and methods which will guide the coal storage committee in its work. The support and coöperation of all engineers in the consummation of this work are most earnestly requested.

P. F. Walker.[1]

[1] Dean of Engineering, University of Kansas; Field Executive, F.A.E.S. Committee on Coal Storage.

Southern Appalachian Power Conference Holds Annual Meeting

THE second meeting of the Southern Appalachian Water Power Conference, established in June, 1922, was held at Asheville, N. C., June 25–27, 1923. The adoption of the report of the Executive Committee on the future policy, work, and influence of the Conference was the outstanding event of the meeting. This report proposes the establishment of three bureaus to assist in carrying out the policy of the Conference, which is the "wise and beneficial development, utilization, and conservation of the great water powers, forests, and other natural resources of the Southern Appalachian states."

The bureaus which the plan contemplates are (1) a Bureau of Public Relations, "to effect a more harmonious relation between public utilities, public service regulatory bodies, and the general public;" (2) a Bureau of Industrial Development to "collect, collate, and disseminate accurate and reliable information regarding power and other factors in industrial expansion;" and (3) a Bureau of Research to "compile and digest technical data of value to hydraulic engineers, industrial chemists, and other professional men having to do with the utilization of the Natural resources of the South."

Resolutions were adopted urging the restoration of the original Congressional appropriation of \$2,000,000 for the purchase of forest lands on the headwaters of streams, the increase of the appropriation for coöperation with the states in forest-fire prevention to at least \$1,000,000 a year, and the extension of river navigation wherever possible by the building of navigation-power dams. J. H. Wills, Atlanta, Ga., was elected president for the coming year, and the name of the organization was changed to the Southern Appalachian Power Conference. Interesting papers on power development methods used in surveying a large river system, possible use of large crude-oil engine units for stand-by power plants, etc., were presented.

Federal Power Commission Reports on Distribution of License Fees for 1922

THE FEDERAL POWER COMMISSION announces that it has complete collection of the fees due the Government from operations during 1922 under licenses for water-power development, and has deposited the total of \$29,519.23 in the Treasury for distribution and credit as follows:

To the general fund of the Treasury	\$12,825.21
To the indefinite appropriation (under administration of the War Department): Maintenance and operation of dams and other improvements of navigable waters	12,386.41
To the Reclamation Fund	1,755.21
To Indian funds	1,236.00
To Payments to states under the Federal water-power act, special funds	1,316.40
Total	\$29,519.23

The Commission's receipts from this source during 1921 were \$8,963.57. For 1923 they are expected to be \$60,000. Its operating expenses, exclusive of salaries of assigned personnel, for the years 1921–1923 will not exceed \$107,000, as now estimated. It is expected that within five years from the date of approval of the act (June 10, 1920) the charges collected will have offset all expenses, direct and indirect, in its administration.

Coffin Foundation Makes First Award

THE Southern California Edison Company, Los Angeles, has been selected from eighteen electric light and power companies which submitted records for consideration, as the one which has made the most distinguished contribution to the development of electric light and power for the convenience of the public and the benefit of the industry during the past year. The award, consisting of a gold medal and one thousand dollars, was presented to John B. Miller, president of the company, by Frank W. Smith, chairman of the prize committee of the Charles A. Coffin Foundation, during a meeting of the public policy committee of the National Electric Light Association on June 7, 1923.

Captain Robert Woolston Hunt

LESS than a month after receiving the high honor of the Washington Award "for his pioneer work in the development of the steel industry in the United States and for a life devoted to the advancement of the engineering profession," Captain Robert Woolston Hunt died at his home in Chicago on July 11, 1923.

Captain Hunt was born December 9, 1838, in Fallsington, Bucks County, Pa. His father, Dr. Robert A. Hunt, died when he was only sixteen years of age, and in 1857 the family moved to Pottsville, Pa., where Robert spent several years in the iron rolling mill of John Burnish & Co., acquiring a practical knowledge of puddling, heating, rolling, and other details of the iron-rail business. Later he took a course in analytical inorganic chemistry in a laboratory in Philadelphia, upon the completion of which he entered the employ of the Cambria Iron Works at Johnstown, Pa. The first analytical laboratory maintained in America by an iron and steel company was established under his direction in 1860 for the Cambria Works.

In the Spring of 1861, as night foreman of the Elmira rolling mill, Elmira, N. Y., Captain Hunt assisted in the organization of the working force and the starting of that industry. In the Fall of that year he entered the U. S. Army, and was stationed at Harrisburg. In 1862 he was put in command of Camp Curtin, at Harrisburg, with the rank of captain. The next year he served the state of Pennsylvania as mustering officer, and in 1864 assisted in recruiting Lambert's Independent Mounted Company of Pennsylvania Volunteers.

After the close of the war Captain Hunt returned to the employ of the Cambria Iron Company and was sent to the experimental Bessemer works at Wyandotte, Mich., owned jointly by the Cambria Company and the Kelly Pneumatic Process Company. The Kelly plant had in 1864 produced from pig iron remelted in a reverberatory the first pneumatic steel made in America, and Captain Hunt, while in charge of the works there, introduced the use of a cupola for remelting. In 1866 he returned to Johnstown, where he had charge of the hammering and rolling of steel and superintended the rolling of the first steel rails made in America on a commercial order, produced for the Pennsylvania Railroad from ingots cast by the Pennsylvania Steel Company's plant at Steelton, Pa. The behavior of these ingots led to the successful introduction of blooming by rolling instead of hammering.

The Bessemer plant of the Cambria Company, finished in 1871, was designed and built by John Fritz, chief engineer of the company, with the assistance of A. L. Holley and Captain Hunt. It embodies several new features, such as the continuous running of the cupola, and a new system of bottom casting. Captain Hunt was in charge of these works from the time of their completion until August, 1873, when he resigned to become superintendent of the Bessemer Works of John A. Griswold & Co., at Troy, N. Y. These works were enlarged and remodelled, and the name of the company changed, first to the Albany & Rensselaer Steel & Iron Co., and later to the Troy Iron & Steel Co. Captain Hunt remained in charge until 1888, and during these years he supervised the erection of three large blast furnaces, and made many grades of Bessemer steel not previously produced in America, notably soft steel for drop forgings. He was also a pioneer in the production of steel for gun barrels, carriage axles, drills, and springs. He took out several patents on steel and iron metallurgical processes and machinery, and the Hunt-Jones-Suppes rail-mill feed tables developed during this period, were used later under licenses by the majority of the rail mills in the United States.

In 1888 Captain Hunt resigned his position at Troy and went to Chicago, where he established the firm of Robert W. Hunt & Co., consulting engineers, an organization which now has offices and laboratories in many cities.

Scientific and engineering ability and strict integrity characterize the business enterprise which bears his name, and one of the sources of great satisfaction to Captain Hunt as he approached the end of his long life was that he had been able to place this organization upon a basis which will enable those who were his supporters and assistants to continue the work indefinitely.

The Washington Award is one of many tributes to the work of Captain Hunt. In 1912 he was awarded the John Fritz Medal, "for his contributions to the early development of the Bessemer Process," and in 1920 the Hunt Medal "for meritorius contributions to the art of making steel." He was for many years a trustee of the Rensselaer Polytechnic Institute, which in 1916 conferred upon him the honorary degree of Doctor of Engineering. While residing in Troy he was elected for four successive terms Commander of John A. Griswold Post, No. 338, G.A.R.

In the development of the engineering societies he has played an important part. He was president of the A.I.M.E. in 1883 and again in 1906; president of the A.S.M.E. in 1891; president of the Western Society of Engineers in 1893; president of the American Society for Testing Materials in 1912; and American Vice-President of the International Association for Testing Materials in 1914. He belonged also to the A.S.C.E., the Institution of Civil Engineers, the Institution of Mechanical Engineers, the Canadian Society of Civil Engineers, and the British Iron and Steel Institute. Captain Hunt was secretary of the Committee on Standard Rail

ROBERT W. HUNT

Sections appointed by the A.S.C.E., the final report of which was made in 1893, and of the Special Committee on Rail Sections, appointed in 1892, which reported finally in 1910. The sections recommended by this committee were generally adopted by the railways of America.

His services as an officer and on committees of these societies, as well as his contributions to their proceedings, and lectures before educational and scientific bodies, have been of inestimable value. He was an honorary member of the A.I.M.E., A.S.M.E., American Society for Testing Materials, and Western Society of Engineers.

Captain Hunt was a member also of many athletic and social clubs, and in them, as in all his contacts with his fellow men, had many friends. He placed high value upon these friendships, saying in one of his last public addresses, at the time of the presentation of the Washington Award, "If ever a man has lived who has been blest with the friendship of his fellowmen, it has been myself. Never in my long life have I experienced a moment that, for any reason, I could say I was without friends."

Engineering and Industrial Standardization

Secretary Hoover Advocates Uniform Specifications in Making Government Purchases[1]

I HAVE, with the approval of the state governors, called this conference upon "Specifications" for purchase of supplies by our national and local governments and public institutions. This bald statement of purpose might appear to the uninitiated as a question of little importance. As a matter of fact in its ramifications it means hundreds of millions of dollars to the taxpayer and much more to the private consumer and to the manufacturer. It is an important link in the whole great chain of elimination of waste in our industrial and commercial fabric.

Specifications are the formulated, definite, and complete statements of what the buyer requires of the seller. They must be an accurate representation of the chemical and physical characteristics of the article or material required—and they must be adapted to the best practice of production and distribution.

The first step in formulation, therefore, is the determination of these chemical or physical characteristics and this brings us to the entire field of standardization of commodities; that is, the determination of qualities, of grades, of purposes and performance. Scientific standards, of course, are of old origin; Emerson defined a standard as "That which is established by investigation or authority to be reasonably attainable maximum of desirability." Their formulation requires the services of chemists, physicists, engineers and something that has been often neglected, the added experience of the manufacturer, the producer and the user. There is no economy to be obtained.

Standardization insures quantity production and hence lower production cost; smaller investment of capital and, therefore, the release of capital for other industrial purposes and developments.

Specifications and standards are a changing requirement, for there is steady progress in the arts and invention; and requirements, therefore, must be subject to periodic review.

Being aware from war experience of the great faultiness of specifications used in Federal purchases, I undertook early in this administration that the Department of Commerce should review these specifications. Subsequently, with the establishment of the Bureau of the Budget, an interdepartmental committee was created for the better development of this work, at the suggestion and under the leadership of the Department of Commerce. Each of the specifications are being taken in hand and the chemical and physical requirements of each article in question are being exhaustively examined in the laboratories of the Bureau of Standards. Beyond this, however, after we have arrived at definite scientific background, the manufacturers in each branch are being brought into consultation to make sure that the industrial and commercial setting of a given specification is right from the point of view of the practical producer. By so doing we have found that a great many specifications for large purchases were loosely drawn, so that the various manufacturers making bids were offering really entirely different grades and qualities, and that, therefore, a mere monetary difference in price did not denominate relative merits because of the lack of precision in specifications. Moreover, we have found that other specifications were drawn purely from the point of view of the personal vision of some official, and as drawn required special manufacture, when well-known articles, already standardized, necessarily bid a price that would warrant special production and consequent interruption of ordinary business.

Now, all these reorganized specifications are enabling the Government to buy on much better terms and at savings to the taxpayer. This conference, therefore, has been called with the thought that the Federal government—with its great laboratories and with its large experience in the standardization of purchases, in the formulation of the sequent specifications, and in the development of methods of testing—could be of service to the purchasing agencies of states, municipalities, and public institutions.

Especially in research work and in the elaboration of methods of testing can the Federal Government and its laboratories be of value to purchasing agencies and industry generally. Research is a necessary component of standardization and the formulation of specifications.

This whole question is proving to be of vastly greater importance than even the savings on public purchases might imply. Industry itself has long struggled to establish standards and to secure their acceptance as a method of simplifying the process of manufacture and raising the ethics of production. Furthermore, where standards and specifications are successfully developed by the Government through the methods we have undertaken, they are receiving wide voluntary acceptance and adoption among public consumers. I need only to point to the case of cement, where practically the whole output of the country is now produced and distributed on the basis of Federal standards and tests—it being sufficient in the purchase of cement simply to state "Federal specifications."

Now I do not wish to give the impression that specifications must be newly discovered in order to be proper and advantageous. Our engineering and professional societies, especially the American Society for Testing Materials and the American Engineering Standards Committee, have long been engaged in the preparation and standardization of certain types of specifications; our university laboratories, our great industrial laboratories, the engineers in our large industries, have for years been developing specifications in a great multitude of materials. Many of these specifications have lain dormant for lack of use by the consumer in his demands upon the producer. Others of them have not had applied to them the test of commercial experience in production. It is our purpose to adopt whatever is good, to put it under review as to its practical application, and, as we have done hitherto, to call in the expert manufacturer and producer for his coöperation and advice.

There are a great many directions in which this problem of waste elimination and increased efficiency extends. It extends even into such problems as an ample transportation system. But a very large opportunity for the elimination of waste and the increase of efficiency lies in the field that I have been describing to you today. It is a field of much larger dimensions, in hundreds of millions and billions of dollars, than will be believed by any except men of professional experience; it is proposed to seek your cooperation in this field, not only for the purpose of decreasing the cost of supplies in public purchases, but also in the influence that the consumer can exert in coöperation with the producer to minimize the costs of production and distribution.

I could formulate these propositions into terms of reducing the cost of living, or I could formulate them into terms of raising standards of living. Whichever economic phrase we may adopt, they both lead to the same end—and that is the increased comfort and happiness of our people.

Items of Interest in the Standardization Field

Telephone Group Organized. At a recent meeting of the U. S. Independent Telephone Association it voted to take membership in the A.E.S.C. with one representative. This Association with the American Telephone and Telegraph Company will therefore constitute the Telephone Group.

N. A. of P. A. Discuss Standardization. Dr. P. G. Agnew, Secretary of the A.E.S.C., told the National Association of Purchasing Agents at their annual convention in Cleveland that the purchasing agents of state and municipal government departments are spending approximately $700,000,000 yearly for supplies, materials of construction, and other products. During his address he pointed out how much of this amount becomes a direct waste, then told of what his committee is doing to eliminate a part of this waste.

Methods of Analysis of Paint Pigments. Many of the controversies growing out of differences in methods of analyzing paint pigments should be eliminated by the universal use of the method for routine analysis of white pigments, yellow, orange, red and brown pigments, containing iron and manganese, and of dry red lead, which have just been approved as Tentative American Standards by the

[1] Abstract of address delivered at a Conference of State Purchasing Agents, Washington, D. C., May 26, 1923.

American Engineering Standards Committee. The approved methods provide a basis for the analysis of paint pigments, which has always been a complicated and often a controversial problem. The specifications for these methods of analysis were presented for A.E.S.C. approval by the American Society for Testing Materials under whose auspices the specifications were developed, and the A.S.T.M. has been designated as sponsor for these specifications.

Sponsors for Road Material. The American Engineering Standards Committee announces the appointment of the following four organizations as joint sponsors for the specifications of the Method of Test for Penetration of Bituminous Materials submitted by the American Society for Testing Materials: American Association of State Highway Officials, American Society for Municipal Improvements, American Society for Testing Materials, and the Bureau of Public Roads. This is only one of several standardization projects involving road materials now before the American Engineering Standards Committee,, the others covering the toughness of rock, the distillation of bituminous materials, and specifications for concrete.

Paper-Stock Sheet Sizes. One of the net results of a broadly representative conference which met in Washington on June 19 was the final adoption by the manufacturers' and users' organizations of the following four standard sheet sizes for book-paper sizes:

25 in. by 38 in.	38 in. by 50 in.
26 in. by 29 in.	29 in. by 52 in.
32 in. by 44 in.	44 in. by 64 in.
35 in. by $45^1/_2$ in.	

This conference also agreed that the standard method of determining the basic weight or "substance" of a given sheet of paper shall be on a ream 25 in. by 40 in. of 500 or 1000 sheets for all paper.

Aeronautical Safety Code. The Sectional Committee which is developing the American Aeronautical Safety Code held a meeting recently at the Bureau of Standards. At this meeting the committee adopted reports of two sub-committees consisting of rules for balloons, airships, landing fields, seaplane stations, and airways. These parts of the code are now available for general use and application.

Steel Bridge Standards. The American Railway Engineering Association has submitted its General Specifications for Steel Railway Bridges and its Specifications for Movable Railway Bridges for approval by the American Engineering Standards Committee as American Standards.

Protection Against Lightning. The Sectional Committee on Protection Against Lightning organized jointly by the Bureau of Standards and the American Institute of Electrical Engineers, has been active in the preparation of a tentative standard for the protection of buildings and other property against lightning. A joint meeting of Group I of the Sectional Committee in charge of the work, together with the National Fire Protection Association's Committee on the same subject, was recently held in Chicago. Copies of the tentative standard have also been circulated generally for comment by those interested, and the final draft is now being worked out.

Roller Chains and Sprockets

(*Continued from page 503*)

las are special for cutters covering the standard ranges of teeth·

$$W = 1.24D \cos Yab;\quad V = 1.24D \sin Yab$$

$$yz = D\left[1.24 \sin\left(17° + \frac{148}{T} - Yab\right) - 0.8 \sin\left(18° - \frac{28}{T}\right)\right]$$

$$F = D\left[0.8 \cos\left(18° - \frac{28}{T}\right) + 1.24 \cos\left(17° + \frac{148}{T} - Yab\right) - 1.3\right]$$

$$cb = c'b' = \sqrt{(E + F)^2 + yz^2}$$

Width of cutter $= Q = 1.02 \sin (180°/n) \times$ outside diameter of the smallest sprocket in the range to be cut, to the next higher 32nd inch.

Thermal Conductivity of Liquids

(*Continued from page 482*)

B.t.u. per hr. This rate is taken at the surface B or 0.81 in. below the heater. Hence

$$K = \frac{300 \times 4.13}{(180 - 80) \times 1 \times 3} = 4.13.$$

Correcting for losses as explained above, K becomes $4.13 \times 1.16 = 4.79$ B.t.u. per sq. ft. per degree difference in temperature per inch per hour.

The computed values of K are given in Table 2. In this table the 1.16 correction has not been applied. It should be noted that, partly owing to reasons of time, computed results are tabulated only for temperature gradients $(T_1 - T_2)/L$ having values between 17 to 24, although the gradient values varied between 4 and 43.

For purposes of comparison, the available data upon the conductivity of water and their variation with temperatures were collected and plotted as in Fig. 7. This material was in c.g.s. units and was converted into the English system by multiplying by 2.90×10^3. The names of the authorities are given, and it can be seen that there is a wide variation in the results. The curve drawn through these points was made upon the popular assumption that K varies directly as the temperature.

As can be seen from Fig. 7, the conductivity as determined from these tests falls below the assumed curve based on results of previous investigations. It was unfortunate that the average temperature was not low enough to give a better chance of checking. The only close check is for 110–115 deg. Here Lees obtained 3.5 while the value in the author's test was 3.65. Lees' data contradict those of other authorities, K decreasing with an increase in temperature in his results.

Discussion of Results

In carrying out the work there were a number of sources of error that were not eliminated. For instance, the results should be multiplied by 1.16 to correct for heat losses, assuming the condensate method of measuring the heat input to be correct. There is uncertainty as to just what takes place between the heater and the liquid surface. The thermocouples indicate a condition of turbulence, which would lead to the belief that the surface contact was not good. If this were so, considerable heat would be lost in penetrating the pocketed air space. With good surface contact, another factor might enter into the problem. With the top water layers at higher temperatures than the bottom ones, imperfect or unequal expansion would take place. This would tend to increase the pressure within the liquid and might be a source of convection currents. Also, with continuous heating, the temperature of the bottom layers could not be brought to the temperature of the top layers, and this is an indication that heat was leaving through the bottom of the vat or that the water-logged vat became finally a better conductor than the vat.

Notwithstanding these sources of error, a number of tentative conclusions may be drawn. On the whole, the conductivity seems to vary inversely with the temperature, and in Fig. 8, with curves drawn the various points, two curious things are noticeable, the conductivities for the same temperature gradient $(T_1 - T_2)/L$ lie upon a straight line, and the conductivities themselves vary greatly for the same temperatures. Thus at 130 deg. fahr., K is found to be 1.5 and also 4.15. Experimental error may be responsible for this peculiar phenomenon, but in the opinion of the author K depends upon the temperature gradient and not upon the average temperature.

The foregoing conclusions are purely tentative, and the author believes that the subject must be investigated more carefully and with better-constructed apparatus. A container of bakelite might be used. Some means should be available for keeping $(T_1 - T_2)/L$ constant. The source of heat should be of greater intensity than that afforded by steam, so that a greater quantity could be supplied in a given time. Control of the surface contact would be an advantage. Means of measuring the heat passing each section, if one could be devised, would settle the great difficulty of obtaining the flow rate. Lastly, a more sensitive and more accurate means of measuring temperatures would be desirable.

THE ENGINEERING INDEX

(Registered United States, Great Britain and Canada)

Exigencies of publication make it necessary to put the main body of The Engineering Index (p. 107-EI of the advertising section) into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.

AUTOMOBILE ENGINES

Combustion Chambers. Combustion Chamber Design. Automotive Industries, vol. 48, no. 26, June 28, 1923, pp. 1406–1412, 16 figs. Mechanical drawings showing recent developments.

Manifolding. Correct Manifolding a Basic Problem of Vertical Eight, P. M. Heldt. Automotive Industries, vol. 48, no. 25, June 21, 1923, pp. 1328–1330, 7 figs. Carefully worked-out design required to give uniform distribution of gases; firing order closely interrelated; single exhaust manifold may be utilized if of sufficient size.

AUTOMOBILES

Brakes. Renault Adopts Front Wheel Brake for Six Cylinder Models. Automotive Industries, vol. 48, no. 25, June 21, 1923, pp. 1334–1335, 2 figs. Servo mechanism, consisting of friction clutch and equalizer, is mounted back of gear box and driven at low speed by worm and worm-gear combination from tail shaft; high pressure obtained.

Sekine. Novel Design of Chassis and Body Shown in Sekine Car. Automotive Industries, vol. 48, no. 25, June 21, 1923, pp. 1322–1326, 9 figs. Unusual power-plant arrangement; driving at left rear wheel; light, unsprung weight; and simple, sectional-body construction, are features of new vehicle by American engineer for Japanese company.

BOILER FURNACES

Oil-Burning. Boiler-Plant Operation with Fuel Oil, Kingsley L. Martin. Power Plant Eng., vol. 27, no. 13, July 1, 1923, pp. 664–667, 2 figs. Features of fuel-oil burning in its relation to installation, operation and maintenance.

BOILER OPERATION

Heat-Balance Calculation. Graphic Method for Computing Heat Balance, F. A. Sborkey. Blast Furnace & Steel Plant, vol. 11, no. 6, June 1923, pp. 348–354, 7 figs. Convenient way to eliminate errors resulting from use of formulas when computations of boiler-room data are required.

CLUTCHES

Automobile. Recent Clutch Designs. Automotive Industries, vol. 48, no. 26, June 28, 1923, pp. 1392–1397, 14 figs. Mechanical drawings showing recent developments in clutches.

COAL HANDLING

Dock Loading Equipment. Flexible Coal-Loading Dock Equipment. Iron Age, vol. 111, no. 26, June 28, 1923, pp. 1851–1854, 7 figs. War-Department plant near Mobile, Ala., has new design of apparatus to avoid frequent moving of ship along wharf; largely automatic and easily handled.

COST ACCOUNTING

Burden Distribution. The Bugbear of Burden Distribution, G. Charter Harrison. Management & Administration (Management Eng. & Administration Combined), vol. 6, no. 1, July 1923, pp. 49–54, 2 figs. Plan to eliminate its work and worry.

COUPLINGS

Flexible. Flexible Couplings for Steel Mills and Other Drives, John J. Serrell. Assn. Iron & Steel Elec. Engrs., vol. 5, no. 6, June 1923, pp. 177–187 and (discussion), pp. 188–230, 34 pp. How to overcome excessive pulsating overload and excessive misalignment, due to operating accident or abuse. Discussion includes papers by Gustave Fast, P. C. Day, J. H. Albrecht, W. Trinks, R. W. Davis, W. E. Trumpler and L. H. Keim.

CUTTING TOOLS

Multi-Cutting. Multi-Cutting Tool Arrangements, Joseph Horner. Engineering, vol. 115, nos. 2977, 2978, 2980, 2983, 2988, 2990, 2996 and 2998, Jan 19, 26, Feb. 9, Mar. 2, Apr. 6, 20, June 1 and 15, 1923, pp. 63–64, 96–98, 163–165 and 176, 259–261, 419–421, 482–485, 673–675 and 731–734, 174 figs. partly on supp. plates. Jan. 19: Standardization of tool angles; old and later tool shapes compared; roughing and finishing, double-edged, stellite, form-turning and form-profile tools. Jan. 26: Tools used in lathes; examples of multi-cutting. Feb. 9: Tool setting in common and turret lathe; tool holders; turret work. Mar. 2: Multiple-spindle machines. Apr. 6: Drilling and boring; spade cutters. Apr. 20: Vertical boring and turning mill; combination features. June 1: Milling cutters; multiple arrangements; interlocking. June 15: Work on plano-miller; Ingersoll machines; examples of work.

DIESEL ENGINES

Acro. New Diesel Engine May Be Practical for Automotive Use. Automotive Industries, vol. 48, no. 25, June 21, 1923, pp. 1336–1337, 2 figs. Describes recent development invented by Franz Lang, of Germany; compression pressure about 200 lb. per sq. in.; practically instantaneous ignition of fuel charge gives flexible operation; novel injection-valve design; low-grade hydrocarbon oils may be used.

FLOW OF FLUIDS

Electric Flow Meter. The Hyperbo-Electric Flow Meter. Power, vol. 57, no. 26, June 26, 1923, pp. 1024–1025, 3 figs. Meter for measuring pressure variations; readings are guaranteed to be within 2 per cent of actual flow, between 15 and 100 per cent of meter rating, and within 4 per cent of actual flow from 5 to 15 per cent of rating, allowing pressure variations of 20 per cent above or below rating and any temperature or specific-gravity variations.

GEARS

Grinder for. Gear Grinding. Automotive Engr., vol. 13, no. 177, June 1923, pp. 170–171, 3 figs. New machine made by Lees-Bradner Co., Cleveland, O., for finishing hardened gears.

Tooth Forms. Tooth-Forms of Green, Burnished, Hardened and Ground Gears, K. L. Herrmann. Am. Mach., vol. 58, no. 26, June 28, 1923, pp. 933–936 and vol. 59, no. 1, July 5, 1923, pp. 5–9, 15 figs. June 28: Instruments for checking tooth forms and spacing; plotting curves; errors due to inaccurate machines and to hardening. July 5: Changes due to repeated hardening; grinding teeth of spiral bevel gears more important than teeth of spur gears; hobbing machines.

HACKSAWS

Speed of Blades. Requirements in Cutting off Metal, M. E. Erskine. Machy. (N. Y.), vol. 29, no. 11, July 1923, pp. 863–864. Consideration of speed at which blade should travel to secure best results; pressure on blade while cutting; effect of design of hacksaw machine, savings effected by correct means for cutting off metals.

INDUSTRIAL MANAGEMENT

Methods and Principles. The Methods and Principles of Frank B. Gilbreth, Inc. Am. Mach., vol. 59, no. 1, July 5, 1923, pp. 25–27, 2 figs. Route sheet to keep track of materials and parts; instruction sheet; duties of foreman and inspector in keeping production stream flowing smoothly.

INTERNAL-COMBUSTION ENGINES

Suction and Compression Temperatures. Notes on the Estimation of Suction and Compression Temperatures in Internal Combustion Engines, W. Morgan. Automobile Engr., vol. 13, no. 177, June 1923, pp. 189–191, 3 figs. Measurement of volumetric efficiency; charge pressure after closing of inlet valve; estimation of exhaust-gas temperature; measurement of compression pressure.

LABOR

Collective Bargaining. Industrial Government Through Collective Agreements in Germany, Emil Frankel. Management & Administration (Management Eng. & Administration), vol. 6, no. 1, July 1923, pp. 39–42. Origin of collective bargaining in Germany; legal standing and basic principles; extension of territorial validity; subjects covered by agreements; hours, vacations, and contract terminations; attitude of employers and workers; future outlook.

LOCOMOTIVES

Coaling Stations for. New Coaling Station Mixes Fuel Automatically. Ry. Age, vol. 74, no. 29, June 23, 1923, pp. 1533–1534, 5 figs. Accurate proportioning of anthracite and bituminous accomplished with simple equipment at Delaware & Hudson coaling station near Plattsburg, N. Y.

OIL ENGINES

Cold-Starting. A Cold-Starting Oil Engine. Engineer, vol. 135, no. 3521, June 22, 1923, p. 666, 4 figs. 2-stroke, solid-injection type brought out by Petters, Ltd. Yeovil.

German Marine. German Oil-Engines for Merchant Ships, Walter Mentz. Motorship, vol. 8, nos. 5 and 7, May and July 1923, pp. 363–368 and 503–506, 27 figs. Observations on building of oil engines for merchant ships, based on journey by author to all large German works where they are built, including M. A. N.; Blohm & Voss; Deutsche Werke in Kiel; Deutz; Waggon- u. Maschinenbau A. G. Görlitz; Krupp Germania Shipyard; Mannheimer Motorenwerke; Sulzer; Vulkan Works in Hamburg; and Weser Corp. in Bremen.

PRESSURE VESSELS

Welded. An Investigation of Welded Pressure Vessels. Am. Welding Soc.—Jl., vol. 2, no. 5, May 1923, pp. 11–162, 120 figs. Report of Pressure vessel Committee of Am. Bur. of Welding. Recommendation to A.S.M.E. Boiler Code Committe; comments on construction; design; hydrostatic hammer test; insurance; physical quality of materials; chemical requirements of plate; welding wire; tests of welded specimens; marking and stamping; Bureau of Standards report.

PRESSWORK

Pressed Steel vs. Castings. Replacing Castings with Stampings. Machy. (N. Y.), vol. 29, no. 11, July 1923, pp. 873–875, 6 figs. Substitutions of pressed metal to replace thin cast shells made by Worcester Pressed Steel Co., Worcester, Mass.; advantages, among which is increase in strength with reduction in weight.

PULVERIZED COAL

Burning Systems. Various Systems of Burning Pulverized Coal, C. F. Herington. Blast Furnace & Steel Plant, vol. 11, no. 6, June 1923, pp. 345–347, 2 figs. Comparison between bin, air-distribution and unit systems; estimated costs for different types of installations.

PUMPS

Suction. Pump Suction, F. H. Smith. Blast Furnace & Steel Plant, vol. 11, no. 6, June 1923, pp. 322–327 and 330, 5 figs. With special reference to pumps for by-product plants for handling various substances, such as water, ammonia liquor, tar wash-oil, etc.

PRODUCER GAS

Open-Hearth Furnaces. The Production and Utilization of Producer Gas for Heating Open Hearth Furnaces, M. G. Husson. Blast Furnace & Steel Plant, vol. 11, nos. 5 and 6, May and June 1923, pp. 264–268 and 328–330, 3 figs. Translated from Revue de l'Industrie Minérale.

RAILWAY REPAIR SHOPS

Locomotive. New Burlington Locomotive Shop at Denver, A. H. Ostberg. Ry. Age, vol. 74, no. 29, June 23, 1923, pp. 1647–1649. $2,500,000 project will employ 750 men, and turn out 200 classified and 50 running repairs a year.

Mallet Locomotives. New Mallet Shop Has Interesting Features. Ry. Age, vol. 74, no. 29, June 23, 1923, pp. 1511–1513, 5 figs. West. Maryland completes modern unit at Port Covington, Md., for repair of heavy power.

ROLLING MILLS

Speed Control. Speed Control of Latest Mills at Gary, Gilbert L. Lacher. Iron Age, vol. 111, no. 26, June 28, 1923, pp. 1832–1834, 4 figs. Two new strip mills have adjustable-speed motor drive; presents novel method of handling coil stock from mill to warehouse; typifies material-handling equipment.

STANDARDIZATION

Economic Hindrances to. Economic Hindrances to Standardization, Walter J. Matherly. Am. Mach., vol. 58, no. 26, June 28, 1923, pp. 937–939. Fundamental problem of economic change; analysis of hindrances to such a change; conservative policy of manufacturers regarding changes in methods of production.

STEAM-ELECTRIC PLANTS

Indiana Electric Corpn. Wabash River Station of the Indiana Electric Corporation, Frank S. Clark, Power, vol. 57, no. 26, June 26, 1923, pp. 1008–1013, 3 figs. First section of 100,000-kw. plant being constructed close to coal fields; outstanding features are 350 lb. steam pressure, high boilers, stage bleeding, house turbine for emergency only, evaporators and special provision for 31-ft. rise and fall of river.

Kansas City, Mo. Northeast Station, Kansas City, Mo., Adds 30,000 Kilowatts, Thomas Wilson. Power, vol. 58, no. 1, July 3, 1923, pp. 2–7, 5 figs. Boilers of latest design supplying steam at temperature of 650 deg. fahr., are equipped with forced-draft chain grates and high-pressure counterflow economizers, and provision has been made for plate-type air preheaters.

Power Costs. Analyzing Power Costs in Small Plants. L. V. H. Armstrong. Elec. World, vol. 81, no. 26, June 30, 1923, pp. 1512–1516, 16 figs. Investigation of various factors involved; use of turbine and oil engines in typical installations; influence of load factors on selection of prime mover. (Abstract.) Paper presented before Atlanta Section, Am. Soc. Mech. Engrs.

STEAM TURBINES

Mixed-Pressure. Calumet & Hecla Large Mixed Pressure Turbines. Power, vol. 58, no. 1, July 3, 1923, pp. 10–12, 3 figs. 2-cylinder, mixed-pressure turbines utilizing exhaust steam from number of copper stamp heads, with supplementary supply of live steam first passing through high-pressure cylinder.

STEEL CASTINGS

Heavy-Type Generator. Casting Heavy-Type Generator Castings. Iron Trade Rev., vol. 73, no. 1, July 5, 1923, pp. 42–43, 2 figs. Method of casting part of rotor of 87,000-hp. unit being built at Schenectady works of Geo. Elec. Co. Casting is 21 ft. in diam. when finished, and 10 of them are required in construction of single generator.

STRUCTURAL STEEL

Yield Point. Experiments on the Yield Point of Steel under Transverse Tests, Alexander B. W. Kennedy. Engineering, vol. 115, no. 2998, June 15, 1923, pp. 736–738, 1 fig. Results of series of experiments on quality of steel familiar in gun construction.

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Mechanical Engineering

The Monthly Journal Published by

The American Society of Mechanical Engineers

Publication Office, 207 Church Street, Easton, Pa. Editorial and Advertising Departments at the Headquarters of the Society, 29 West Thirty-ninth Street, New York

Volume 45 September, 1923 Number 9

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DEPARTMENTAL

ADVERTISING

Price 50 Cents a Copy, $4.00 a year: to Members and Affiliates, 40 cents a Copy, $3.00 a Year. Postage to Canada, 75 Cents Additional; to Foreign Countries $1.50 Additional. Changes of address should be sent to the Society Headquarters.

Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879.
Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921.

Contributors to This Issue

The National Advisory Committee for Aeronautics, the results of whose work is told in this issue in Making America Independent in the Air, is composed of twelve members nominated by the President and serving without salary To all practical purposes the Committee has charge of all the research work in aeronautics in this country of a general character, and in addition considers all aeronautical inventions submitted to the Navy. It has a laboratory of its own at Langley Memorial Field and arrangements for carrying on experimental and research work at the Bureau of Standards and the engineering departments of several universities and technical schools. The Committee issues a series of bulletins on various subjects of research and voluminous yearly accounts of the work done. It also maintains agents in several countries of Europe, who report to America the aeronautical progress abroad. Unless the matters of research are ear-marked especially confidential by the U. S. authorities, all completed research is published.

FREDERICK W. COWIE

* * * * *

Frederick W. Cowie is the author of the paper on The Port of Montreal, and very fittingly too, for he is consulting engineer of the Harbor Commissioners of Montreal. He was born in Caledonia, Ontario, in 1863. He received his B.S. from McGill University in 1886 and was then appointed assistant engineer under the late Sir John Kennedy, a noted port engineer, and at that time chief engineer of the Montreal Harbor Commissioners. Since that time Mr. Cowie has continuously devoted his service to this very important branch of engineering work. Having had the advantage of training and association with Sir John Kennedy, Mr. Cowie was made consulting engineer of the Commission when the former died.

Mr. Cowie is recognized as a harbor-engineering authority and has recently been appointed as expert adviser of the Hampton Roads (State) Port Commission, where his duties will consist in aiding the State Commission to prepare a report and recommendations to the next General Assembly of Virginia, visualizing the future of Hampton Roads as a state asset.

Included in recent work Mr. Cowie has done on the Atlantic seaboard are surveys and reports with recommendations on the harbor of Boston, and a comprehensive plan on the development of Savannah as the State port of Georgia. In 1914 the Council of the Institution of Civil Engineers (Great Britain) awarded Mr. Cowie the coveted Telford gold medal for his paper on The Transportation Problems in Canada and Montreal Harbor. He is a member of the Engineering Institute of Canada.

* * * * *

Carroll R. Thompson, assistant director of the Department of Wharves, Docks, and Ferries of the City of Philadelphia, contributes an article on Material-Handling Problems in Pier Design. Mr. Thompson was born in Philadelphia, Pa., in 1885, and is one of the youngest executives to fill such a position where his duties combine those of chief engineer and supervisor of new construction and the maintenance of the existing port equipment. He deserves a very considerable part of the credit for the recent rapid development of Philadelphia's waterfront facilities and the consequent growth of the port.

CARROLL R. THOMPSON

Mr. Thompson is well qualified to write on his subject for his previous experience includes six years with the American Bridge Co., one year with the Pennsylvania Steel Co and eleven years in the engineering office of the department in which he is now employed. While connected with this department he had unusual opportunities to become familiar with the port and terminal conditions of other seacoast cities, and has served on a number of committees to investigate and report on them. He is a member of the American Society of Civil Engineers, and of the Society of Terminal Engineers and an associate member of the American Association of Port Authorities.

* * * * *

Alfred Cotton, whose paper on The Determination of Chimney Sizes is included in this issue, was born in Southport, England, in 1871. While serving an apprenticeship from 1885 to 1892 in marine engineering, he received his technical education through university-extension courses and by private tuition. He was then engaged by Thomas Henderson, of Liverpool, for whom he worked in designing mechanical stokers and grates until 1894, when he entered the Port Sunlight Soap Works of Lever Brothers, Ltd., as engineering assistant to the works manager. Here he designed one of the first, if not the first, double-stage centrifugal pumps, which operated with fairly high efficiency and entire satisfaction.

In 1898 Mr. Cotton became assistant chief engineer for Meldrum Brothers, Ltd., working on the design and adaptation of mechanical stokers and forced draft, and collaborating in the development of destructors for generating steam from municipal refuse. He came to America in 1903 and developed the Cotton furnace, which embodied a system of steam-jet forced draft. He manufactured and installed these furnaces and allied apparatus until the war, when he entered the employ of Colt's Patent Fire Arms Manufacturing Co. In 1918 he became chief engineer in the combustion department of the Sterling Blower Co., and in 1919 he took his present position as chief of the research department of the Heine Boiler Co.

ALFRED COTTON

Coming A.S.M.E. Events

The third A.S.M.E. Regional Meeting and the first among the Southern Sections of the Society is scheduled for October 23-24, 1923, at Chattanooga, Tenn. Three technical sessions are being arranged, the first on welding, planned to give practical information to engineers and executives, the second on power problems, and the third on management. The latter is especially appropriate as the week of October 22-27 is Management Week, in which some fifty-odd A.S.M.E. Local Sections and about twenty-five sections of other societies will participate.

MECHANICAL ENGINEERING

Volume 45 September, 1923 No. 9

Making America Independent in the Air

The Inception of the National Advisory Committee for Aeronautics, Its Organization for Research, and the Results It has Achieved at the Langley Field Laboratory

When the United States went into the World War in 1917 the importance of aircraft from a military point of view was fully realized, not only abroad where they had had ample experience with it, but also in this country. As a result of this realization a huge appropriation for aircraft, amounting to $640,000,000, was passed practically without discussion by Congress. To build an airplane, however, it is necessary to have money, factory facilities, raw materials, brains, and a knowledge of the laws governing the design and operation of its novel machinery.

This knowledge at that time was entirely lacking in this country and the United States had to go to England, France, and Italy and borrow from them the complete designs of the planes in which our young men were to fight the enemy. The DH-4, the Bristol, and practically all other types except training planes were all copies of foreign products, and there is good reason to believe that they were not improved in their American adaptation.

Since the armistice, however, a different spirit has appeared in American aviation. While appropriations for building airplanes by the Army and Navy have been reduced to a limit which is considered dangerous by the enthusiasts of the new service, a vast amount of research work has been done, with the result that today America may be considered as being practically independent of Europe as far as knowledge of aerodynamics and airplane design is concerned. And much of the credit for this achievement is due to the National Advisory Committee for Aeronautics.

The National Advisory Committee for Aeronautics

This body was established in 1915 for the purpose of supervising and directing the scientific study of the problems of flight with a view to their practical solution, the determination of problems which should be experimentally attacked, and their investigation and application to practical questions of the aeronautics

The Committee consists of twelve members appointed by the President. The law provides that its personnel shall consist of two members from the War Department, from the Office in Charge of Military Aeronautics; two members from the Navy Department, from the Office in Charge of Naval Aeronautics; three members representing respectively the Smithsonian Institution, the U. S. Weather Bureau, and the U. S. Bureau of Standards; and five additional members appointed by the President, all serving without compensation. These five, who may be called expert members, are Jos. S. Ames, Director of the Physical Laboratory, Johns Hopkins University, Baltimore, Md., Wm. F. Durand, Mem. A.S.M.E., Professor of Mechanical Engineering, Leland Stanford Jr. University, Cal., Samuel W. Stratton, Mem. A.S.M.E., President of the Massachusetts Institute of Technology, Cambridge, Mass., D. W. Taylor, Rear Adm. U. S. Navy, Retired, and Orville Wright, Hon. Mem. A.S.M.E., one of the two brothers who originated the airplane. These eminent and busy men could not have been induced by salary considerations to do the work of the Committee, consuming as it does a large amount of time and requiring their frequent presence in Washington, but have undertaken it from patriotic motives for the good of the country.

The task the National Advisory Committee for Aeronautics has set for itself is that of collecting the information necessary to design aircraft of all classes intelligently and to test them reliably. Only those cognizant of the deplorable lack of knowledge regarding aircraft design and operation can have any conception of the magnitude of this task, and when they are made acquainted with the achievements of the Committee they will realize how truly remarkable is the work done by its engineers, especially considering the scanty means at their disposal.

The National Advisory Committee for Aeronautics

From Left to Right:

Dr. S. W. Stratton, President, Mass. Inst. Tech.
Orville Wright, Dayton, Ohio
Major T. H. Bane, Chief Engineering Division, Army Air Service
Dr. John F. Hayford, Northwestern University
Hon. Paul Henderson, Second Asst. Postmaster General (Guest)
Rear Admiral Wm. A. Moffett, Chief, Bureau of Aeronautics, U. S. N.
Prof. Charles Marvin, Chief, United States Weather Bureau
Dr. M. I. Pupin, Columbia University
Rear Admiral D. W. Taylor, Chief Constructor, U. S. N.
Dr. Charles D. Walcott, Chairman, Secretary, Smithsonian Institution
Major General Mason M. Patrick Chief of Army Air Service
Dr. Joseph S. Ames, Chairman Executive Com., Johns Hopkins Univ.

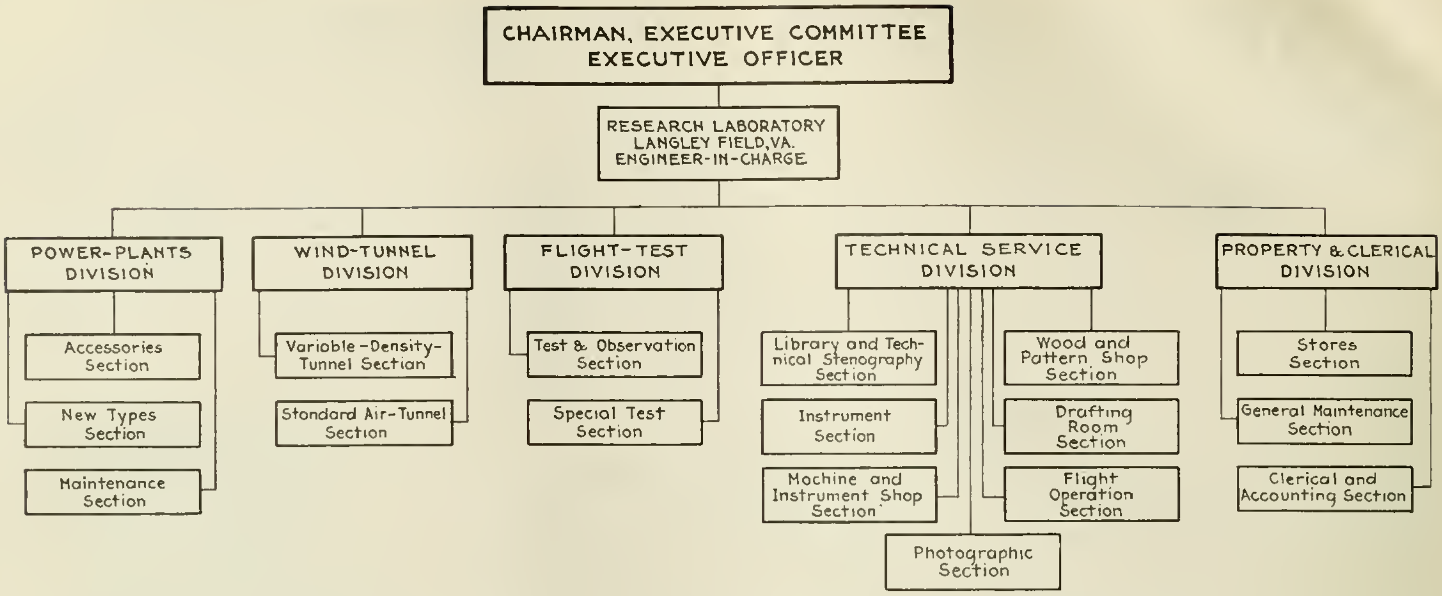

Fig. 1 Research Organization Chart, National Advisory Committee for Aeronautics

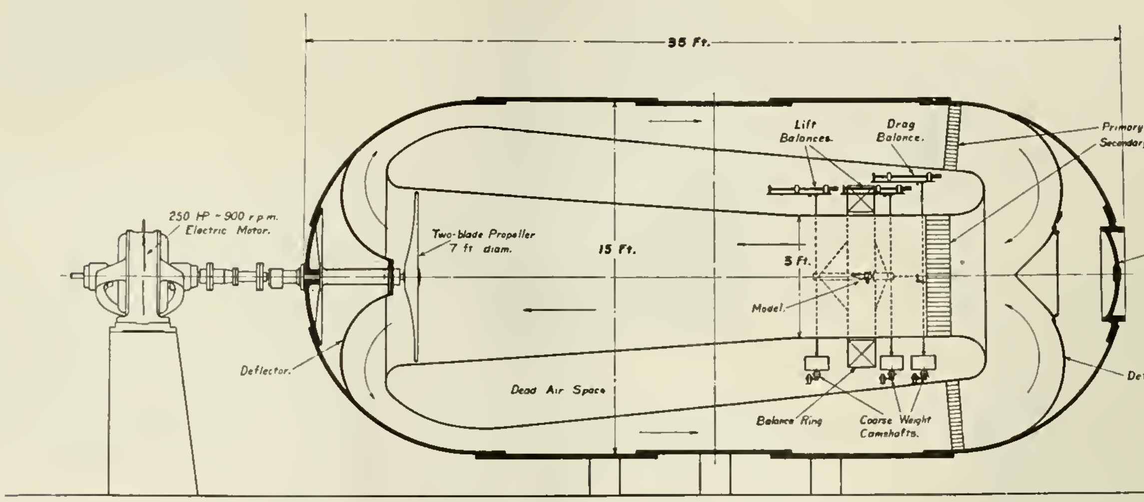

Fig. 2 Longitudinal Section of Compressed-Air Wind Tunnel
(The walls are made of steel plate $2^1/_8$ in. thick.)

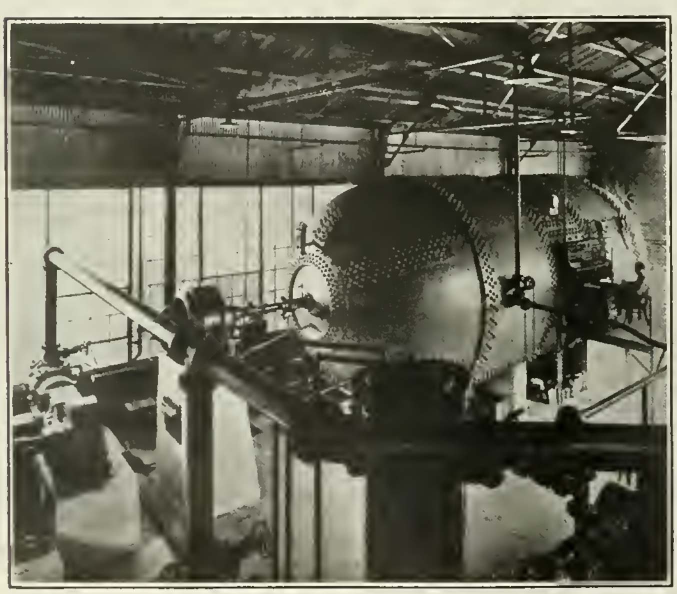

Fig. 3 View of Compressed-Air Wind Tunnel Showing Fan Motor and Air Pipes

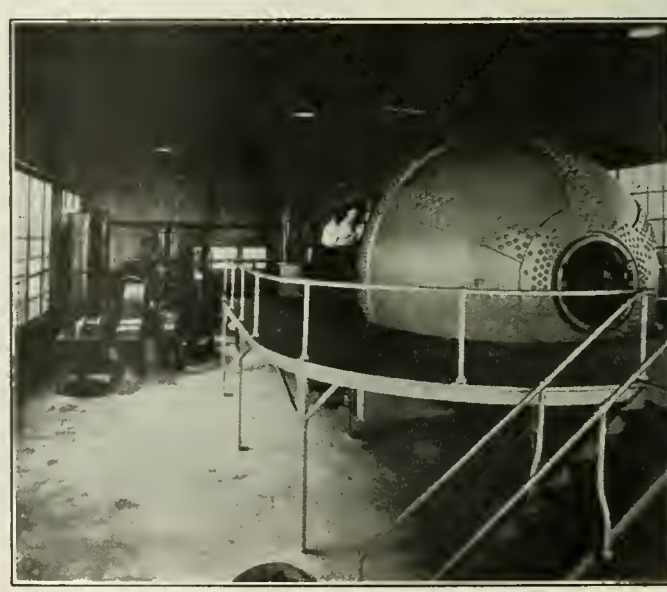

Fig. 4 Compressed-Air Wind Tunnel Showing Observation Platform and Air Compressors

The New Spirit in Aero Engineering

The history of design in aeronautics strikingly resembles that in bridge engineering. The earliest bridges were the work of families of carpenters or stone masons who passed on a few very general and untested rules from generation to generation. They were built by certain rules of thumb without any regard to or analysis of the stresses to which they would be subjected. If the stresses happened to be within the capacity of the bridge, well and good; but if for some reason too great a load was placed on the structure, it collapsed; and while some may have become sadder they seldom became wiser through this experience, and the next bridge was built in substantially the same manner and trust reposed in Providence.

While aeronautics does not cover as many generations as bridge building, it has been but little more scientific. Airplanes were designed at first by inspiration. Sometimes this inspiration was right and a better machine resulted, but exactly why even its designer could not show. At other times inspirational design failed and the machine was abandoned, but not in many cases until it had caused the death of one or more fliers. However, there was no way of telling exactly why and in what respect the proposed design failed. To all practical purposes engineers were "wildcatting" in airplane design.

The testing of airplanes was practically as unsatisfactory as their design. Models could be tested in wind tunnels, but there was no way of determining to what extent the results of a wind-tunnel test would apply on a full-scale model, the so-called law of "dynamical similarity" being one on which entirely too little precise information is available.

In full-flight tests absolute reliance had to be placed on the impressions obtained by the test pilot, which were likely to be tinctured by his changeable state of mind, his ability to report observations exactly, and possibly his personal prejudices for or against the given design. The report of a test to all practical purposes resolved itself into the opinion which the test pilot formed, a purely qualitative conclusion not based on exact scientific data and arrived at by one not trained in the art of exact observation and operating under conditions which did not insure satisfactory precision. It is only natural for an aviator flying a new, unfamiliar, and untested plane to be more concerned with his own safety than with the precise extent to which the plane responds to his maneuvering. All of this created an uncertain, unsatisfactory, and highly unscientific situation. The National Advisory Committee for Aeronautics undertook to remedy it, and the amazing part of it is that while the work is not yet completed, enough has been done to place airplane design and testing on a sound basis and to insure proper precision in the taking of observations.

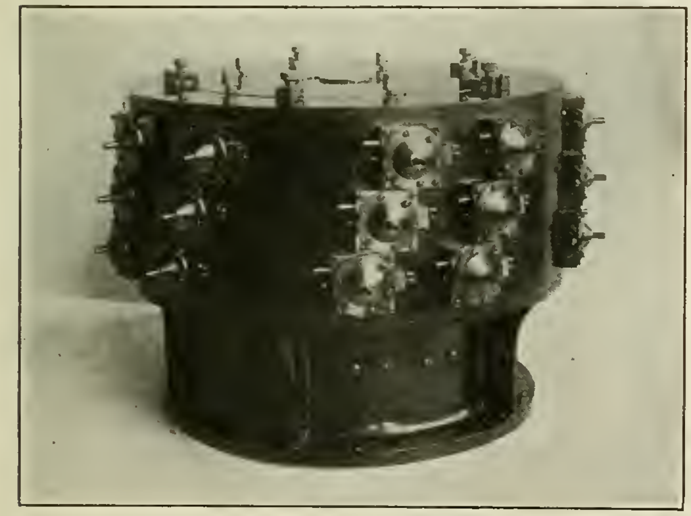

Fig. 5 Multiple Recording Manometer Used in Obtaining the Distribution of Pressure Over Airplane Wings and Surfaces of Dirigibles

To accomplish this required the creation of a research organization unlike anything previously in existence, the design of novel and ingenious research methods and instruments, and the carrying out of thousands of tests in the laboratory, on the ground, and in flight.

Organization of Aeronautical Research by the N.A.C.A.

We shall discuss the organization of research first, which is primarily a management problem that differs from the organization of an industrial plant in many ways.

Organization of research is basically unlike the organization of a manufacturing plant and approaches that of a jobbing machine shop in that, instead of production being essentially a repetition of a given set of operations, every job presents an individual problem entirely novel in its main aspects and one that has to be handled in its own way.

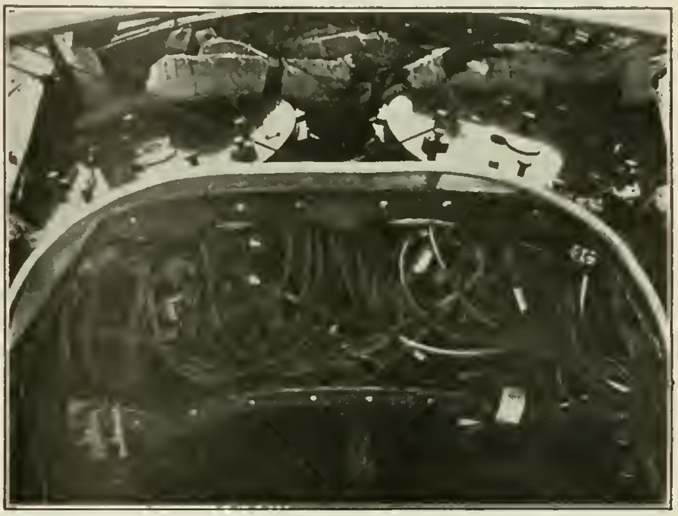

Fig. 6 Multiple Recording Manometer (Fig. 5) Mounted on Cockpit

(This shows also the tubes leading to pressure buttons on various parts of the airplane wing by which the pressure at a given spot is communicated to the manometer.)

In the National Advisory Committee as it is organized, problems may arise in several different ways. A problem may be proposed by the Committee itself or by one of its members; it may be suggested by an outsider or an outside organization, perhaps in connection with an invention submitted to the Committee for consideration; or the Committee may be requested by a Government department, such as the Army or Navy or Post Office, to undertake a research.

Each problem as it arises is referred to one of the three main sub-committees of the Committee and this sub-committee determines broadly the extent to which the problem should be investigated and the organization which should handle it, and submits its recommendations to the main committee. It may thus be handled at Langley Field or at the Bureau of Standards, which latter has a standing arrangement with the National Advisory Committee for Aeronautics for this purpose; or it may be referred by special arrangement to an outside organization such as the Massachusetts Institute of Technology, the University of Illinois, the Leland Stanford Jr. University, or the like, this being done when an outside organization has the proper equipment and personnel to handle the given problem.

It should be clearly understood, however, that the sub-committees of the National Advisory Committee for Aeronautics mark out the program for each given investigation only on very broad lines, especially when the work is to be done in the Committee's own laboratory at Langley Field or at the Bureau of Standards.

The research man is preëminently one venturing into unknown fields. Like David of old he may go out to look for lost asses and find a kingdom. Quite often, however, the contrary happens to be the case. In research it is not unusual to find that apparently minor problems to which scarcely any attention has been paid at the beginning of the work rapidly develop into major ones, and it is not unusual also to find that the problem for which the given research was originally undertaken proves on closer consideration to be no problem at all. Because of this a certain clas-

ticity in instructions is imperative, the governing body, such as one of the main sub-committees, keeping in close touch with the work of the laboratories through progress reports and occasionally through personal observation.

When the problem reaches the Langley Field research laboratory it is then considered at a conference of the engineer-in-charge with such heads of divisions as may be interested in it. For example, a given problem may deal with the determination of the aerodynamic properties of a new wing. In the conference with the engineer-in-charge would be the head of the Wind Tunnel Division, the head of the Instrument Section, and possibly the head of the Flight Test Division. At this conference the general problem of how this piece of research should be carried on is considered, as well as the research facilities available and the new instruments or appliances that have to be provided. A tentative time schedule is established and an estimate of the cost of the given investigation drawn up. Such a conference is usually quite informal, no minutes being kept and each member present taking notes as to what his group should do and when it may call upon other groups to assist in the new undertaking. In addition to this brief conferences of all the heads of the technical divisions and sections are held every week, at which progress reports are made as to work in hand so that all can keep track of what is going on. The general organization of the laboratory may be seen from the chart in Fig. 1.

The laboratory is equipped with a small instrument shop capable of doing work of high precision. As far as possible all heavier and rougher machine work is done by outside contract, although facilities therefor are available in the laboratory if the need is urgent. When it is decided to build a new instrument or piece of apparatus, the practice is to carry the design work in the drafting room only to the extent necessary to establish a proper basis for the construction of the first model. No attempt is made to produce a full set of shop drawings, a complete idea of the design often being present only in the brain of the engineer. As the parts are being completed, it takes shape. Sometimes changes have to be made either on parts already produced or by making entirely new parts. In case the new device is an addition to the family of recording or indicating flight-test instruments, it is tested out first in the laboratory and then in flight. If it is found that its operation approximately meets expectations, changes are incorporated and further tests are made until the performance of the apparatus fully satisfies the requirements or its limitations are determined. While this does not at first appear to be a very scientific or logical procedure, experience has demonstrated that it does lead to the production of satisfactory apparatus with the minimum of delay.

When the apparatus has been definitely completed and tested out by use, complete working drawings are made. This is made particularly necessary by the fact that the research laboratory is not a production shop and ordinarily does not build duplicates of the instruments designed in it, since this can usually be done at somewhat less cost by properly equipped outside shops.

In this connection it may be mentioned that methods have been developed by engineers of the laboratory for handling this work in outside shops. It would have been obviously impossible to write complete specifications for each apparatus. Therefore in the several years of its existence, the laboratory has compiled what might be called a "white" list comprising shops that experience has shown can be relied on to do the work satisfactorily, and it is to such shops that the production of instruments from complete drawings prepared at the laboratory is farmed out. This method, while somewhat informal, has been found to be most productive of results.

Research Personnel at Langley Field Laboratory

As regards the personnel of the laboratory, the engineer-in-charge has stated that experience has shown that the best plan is to employ good men directly after they have been graduated from college and before they have been engaged in any production work. While they may be lacking in practical experience, it has been found easy to instill into them the true spirit of research, a matter somewhat more difficult in the case of engineers who have been taught to concentrate on "getting the work out."

Naturally the turnover in the ranks of the researchers is quite high. After the young men have been at the laboratory a few years they find themselves in possession of a considerable amount of valuable engineering experience and training, and to obtain their services commercial organizations offer them pay far greater than the modest salaries with which the Government compensates its scientific men.

In a way this handicaps the work of the laboratory, but no serious objection can be made, partly because of the gratification natural in seeing men leaving the laboratory to occupy responsible positions in the outside world, but especially since in this way the laboratory comes to occupy the position of a school sending out its missionaries into the industry to teach respect for aeronautical research and methods for bettering American aeronautical products. The industry badly needs such a school, and in training the research force of future American aircraft factories the Langley Field laboratory and its allied organizations are performing a valuable service to the cause of national preparedness.

On a visitor to the laboratory this feature produces a strong impression. Aeronautics from the beginning has been a young man's game, and as one passes from one building of the laboratory to another he constantly meets keen young men with the latest information on their respective subjects at their finger tips. And the amazing thing about it all is that these young men with but scanty financial means at their command are achieving results which are rapidly revolutionizing the industry and converting it from one of unadulterated guesswork into an exact science.

Wind-Tunnel Testing

The Wind Tunnel Division has two tunnels, one of conventional design built of wood, and the other of the so-called "high-pressure" type and of radically novel construction.

The art of testing various wing, airplane, and propeller shapes in wind tunnels has been brought within the last twelve years to a high state of perfection and the instruments developed in this time make it possible to measure and record the performance of a model in a wind tunnel with great reliability and precision. The trouble begins when an attempt is made to interpret the data obtained in a wind tunnel in reference to their application to full-scale machines. There is the so-called law of "dynamical similarity" which purposes to express the relation between results obtained on models and the performance of full-scale machines, but the extent to which and the precise way in which this law should be applied is still a matter of considerable uncertainty.

The compressed-air tunnel, Figs. 2, 3 and 4, represents an interesting attempt to apply a novel principle to the testing of model shapes. Briefly and without going into aerodynamic intricacies it may be said that a model of a length, say, of 6 in. in an air stream having an absolute pressure of 5 atmos. behaves in the same manner as a model 30 in. long would behave in air at atmospheric pressure. In other words, an increase in the pressure of the ambient medium in which a model is tested is equivalent to an increase in the size of the model at approximately the same rate as the increase in pressure.

This is a rather novel departure in testing airplane shapes and not enough work of the kind has been done to show its exact value. It is fortunate, however, that at the Langley Field laboratory sufficient equipment is available to obtain precise data as to the behavior of various wing shapes when incorporated in full-size airplanes in flight, and it may be expected that a comparison between data obtained from the normal-pressure tunnel on the one hand and from the compressed-air tunnel on the other, when compared with data obtained from wings of the same shape in actual flight, will throw a vivid light on the still obscure but highly important law of dynamical similarity.

As shown in Fig. 2, the compressed-air wind tunnel known in the laboratory as Wind Tunnel No. 2 is essentially a riveted tank of quite respectable dimensions, 15 ft. in diameter by 36 ft. long, built of steel plate $2^1/_8$ in. thick, which is none too much considering that the apparatus is designed for working with a maximum pressure of 300 lb. per sq. in.

Inside the tunnel is a propeller which circulates the air and creates the necessary air stream; spy windows are provided to observe the instruments, which latter may be controlled from the outside by the observer.

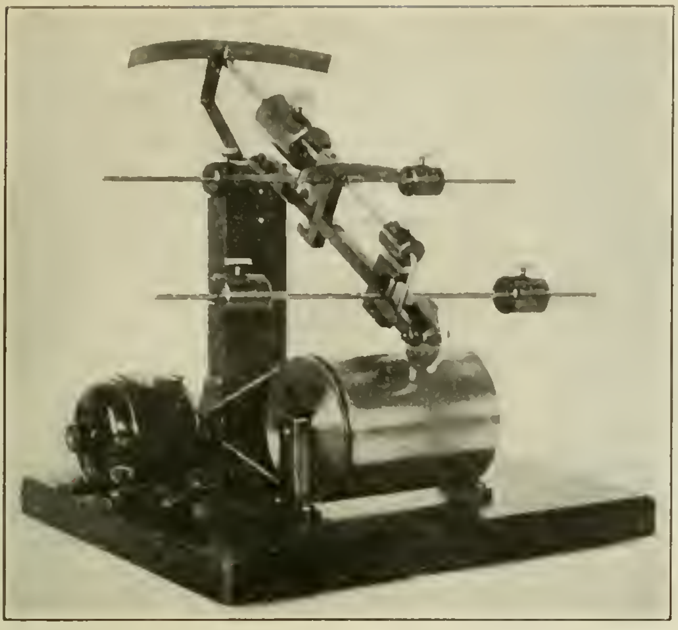

Fig. 7 Apparatus for Indicating Stability Conditions on an Airplane

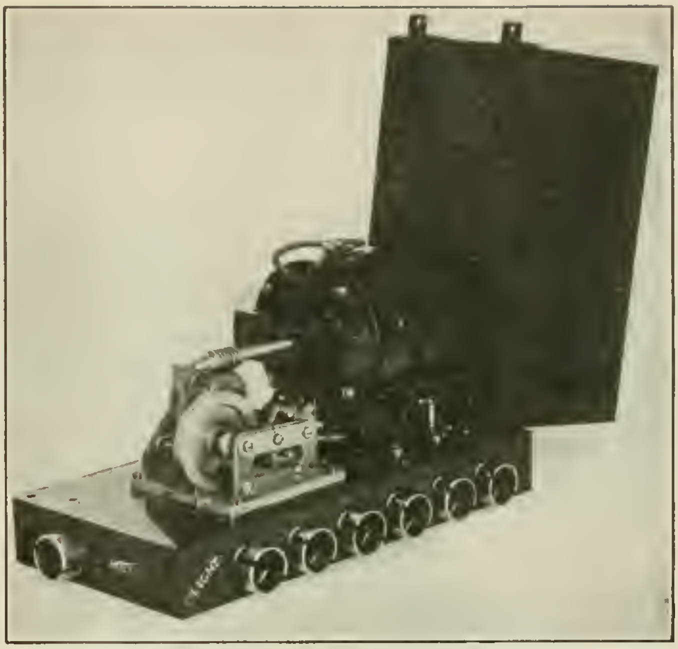

Fig. 8 Electric Contact-Making Chronometer, an Instrument Used in Combination with Other Instruments and Adding the Time Element to the Other Records

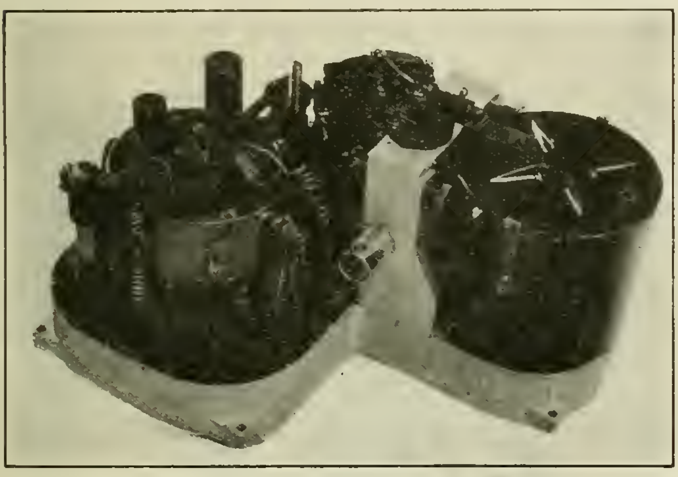

Fig. 9 New Recording G roscope

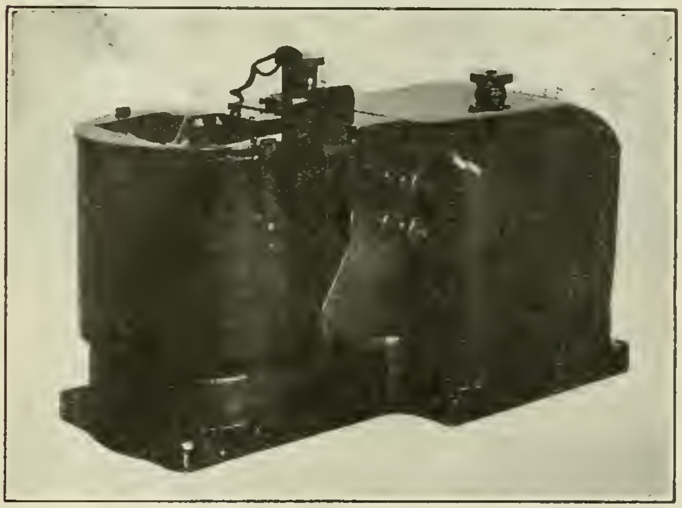

Fig. 10 New Accelerometer Showing the Rate of Variation of Speed of an Airplane

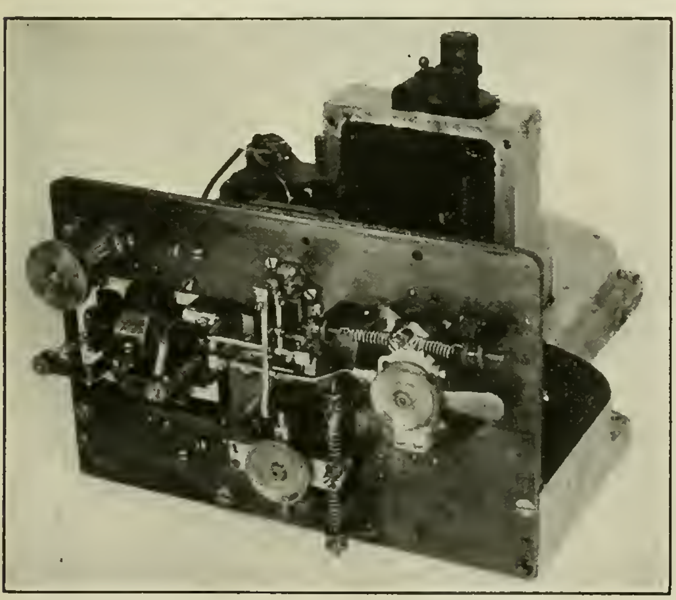

Fig. 11 Three-Component Gyro Turn Indicator, the Purpose of Which is to Inform the Pilot of Any Deviation in Flight from the Straight-Line Direction

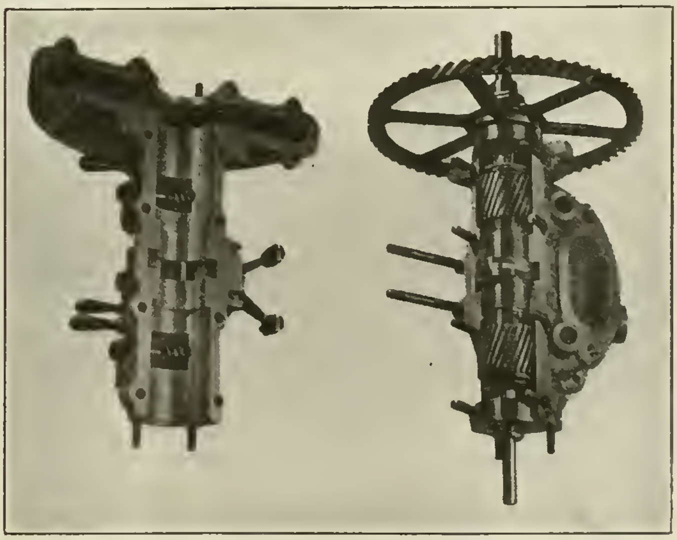

Fig. 12 Valve-Gear Mechanism for Varying Valve Lift of the Universal Test Oil Engine Shown in Fig. 13

Instruments for Determining the Magnitude and Distribution of Stresses in Aircraft

One of the most important problems in the design of either an airplane or a dirigible is the determination of the magnitude and distribution of the stresses in the structure. It is obvious to any engineer that before he can design a piece of machinery he must know what the stresses are in the entire machine and particularly

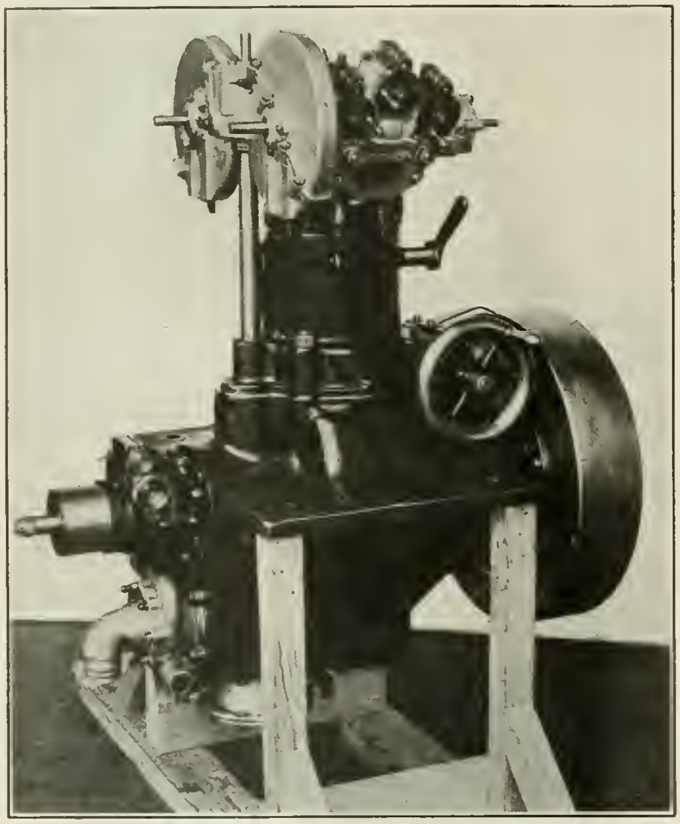

Fig. 13 A Universal Test Oil Engine
(Conditions of operation, such as valve timing, compression pressure, clearance, etc., may be varied while the engine is running.)

the stresses in the parts. This is why we can use a material like cast iron in the foundations, but have to employ steel forgings, possibly special heat-treated alloy steels, in parts rotating at a high speed or subjected to severe vibration. Both airplanes and airships have hitherto been designed in the utter absence of such important data.

While designers for a number of years have known the general nature of the distribution of air pressure over wing surfaces and have been able to apply this knowledge in "sand testing" airplane structures, this mere approximation was found to be untrustworthy when applied to modern high-speed racing and fighting craft, several of which have been the victims of unexpected accidents which were later explained by a more thorough knowledge of the air loads on airplane wings and control surfaces and on airship hulls. The collapse of the Italian-built semi-rigid airship *Roma* in this country and the British-built rigid airship *ZR-2* in England were probably due to lack of adequate load information. The National Advisory Committee for Aeronautics was the first body to undertake a thoroughly scientific investigation of these loads and their distribution, and to carry it through to a successful conclusion.

To do this a new instrument was devised (Figs. 5 and 6) called the multiple manometer, chiefly remarkable for the fact that within a space slightly smaller than a man's silk or stovepipe hat there were crowded thirty diaphragm-type registering manometers. These were connected by small tubing to small brass pressure buttons located at various points of the surfaces of the airplane wing or control surface. The tiny points on the airship in the illustration on the cover of this issue are special "pads" for the same purpose. The pressure at each of these points was transmitted through the rubber tube to the corresponding registering manometer while the aircraft was in actual flight. This permitted recording the variation of distribution of air pressure over the surfaces during various flight maneuvers reliably and without in any appreciable way affecting the behavior of the aircraft itself.

The idea seems to be very simple, but it required an immense amount of thought and engineering design in order to carry it through successfully, and it gave truly amazing results. In the first place, it was found that the distribution of load over the wing of an airplane flying at high speed was decidedly different from what had been anticipated. There have been cases, especially after a rapid dive, where the fabric on the upper side of the wing was actually torn off at the forward edge. There did not seem to be any reasonable explanation for this as the loads were supposed to be of the order of 50 lb. per sq. ft., which was considerably less than the fabric was capable of withstanding.

In the tests of the National Advisory Committee for Aeronautics it was found that the loads reached a maximum of 210 lb. per sq. ft. instead of 50 lb., or were more than 300 per cent greater than hitherto supposed. This means that the forward edge of the wing will have to be reinforced in some way. It will also probably mean that a complete and intelligent redesign of the shape of the wing must be effected to avoid this undersirable localization of the load; and in any event it will mean a more intelligent handling of flight problems themselves.

Another entirely unexpected result of these tests was the discovery of unsuspected extreme load concentration at the wing tips, which explained several instances where the wings had buckled and fliers had been killed. Here the solution of the problem has already been found, namely, altering the wing-tip shape and giving to the wing a negative angle at the rear, a simple matter which

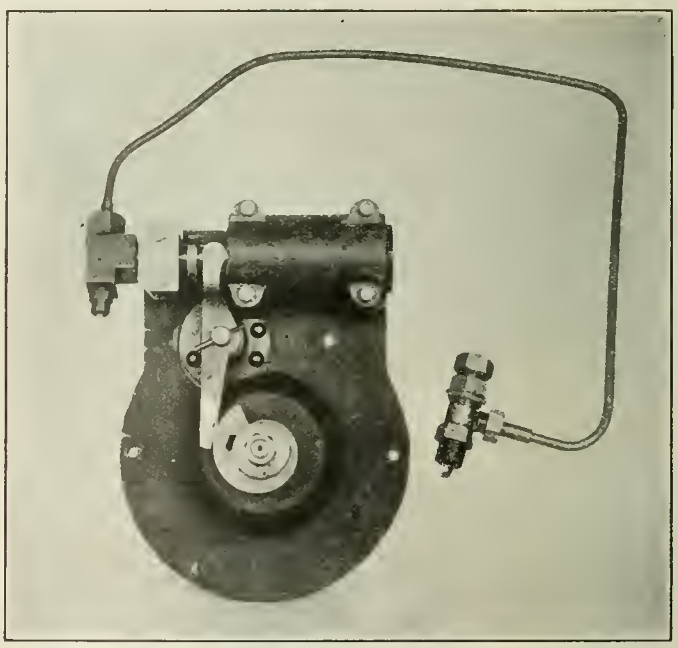

Fig. 14 Fuel-Injection Pump Developed for Use with the Special Single-Cylinder Test Liberty Engine Shown in Fig. 15

will save many valuable lives; and yet it could not have been arrived at without some such methodical and scientific investigation as the Committee and its engineers applied and are applying to the problems of aeronautical design.

While space does not permit going into this matter more fully, the cover illustration shows that the same methods have been employed in the design of airships. Without revealing any military secrets, it may be stated that the results of this investigation have been already taken into careful consideration in the design of the huge Navy dirigible *ZR-1* now under construction at Lakehurst, N. J., and because of this there is reason to hope that it will escape the fate of the *ZR-2* and the *Roma*.

In general, it is the aim of aerodynamical experts of the National Advisory Committee for Aeronautics to place the design of an airplane on the same scientific basis as that which has been employed for a long time in bridge design, where it is possible to know before-

hand the stresses to which not only the entire structure but every one of its members will be subjected. The ability of the materials used to withstand these stresses being known, it becomes possible to specify such factors of safety as will insure the proper functioning of the structure under all but absolutely unforeseeable conditions. This is an undertaking of great difficulty and importance, so difficult, in fact, that no practical attempt at it has been made anywhere outside of this country; and it is a matter regarding which American engineers may feel proud that conclusive results have been obtained within a period of less than three years of work, and with the expenditure of an extremely modest sum of money.

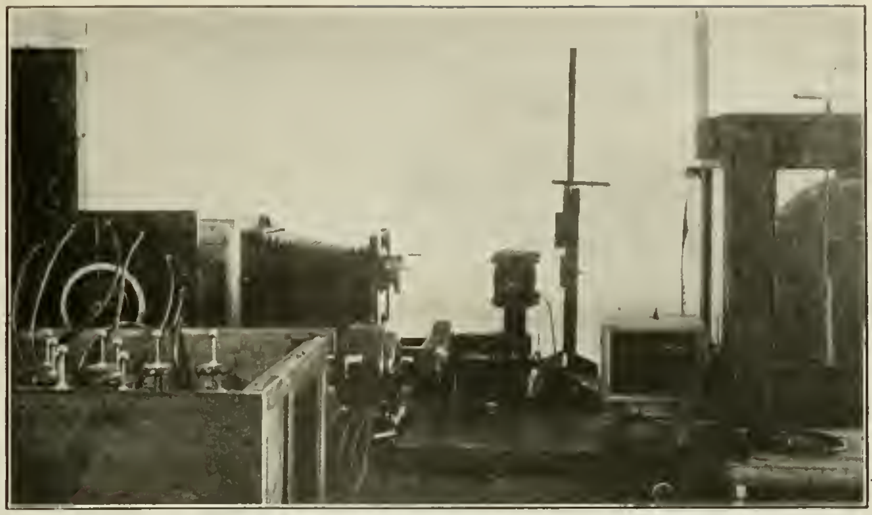

Fig. 16 Apparatus for Obtaining Photographs at a High Rate of Speed (of the Order of 5000 per sec.) to Show Characteristics of Fuel Sprays
(This apparatus is used in connection with work of developing a fuel-injection oil engine for aircraft.)

Flight Testing of Airplanes

"The proof of the pudding is in the eating," but this does not mean that all who eat the pudding will agree as to its qualities. There is presumably about as much variation in the ability of different test pilots to judge of the performance of an airplane, because of the personal element of the flier. Furthermore, there are good grounds for believing that even a reliable test pilot will not always report things as they have actually occurred, no matter how honestly he may try.

In any event, impressions of a test pilot, and that is practically what a report of the ordinary test flight amounts to, are too indeterminate to make a comparison possible. As a result of this there has been in the past no reliable way of determining the qualities of an airplane in flight, in particular its controllability and maneuverability.

To solve this problem the National Advisory Committee has developed a series of instruments which give exact information as to what the pilot does in flight at any given time, and show beyond cavil just what happens as a result of a given action of the pilot.

The most interesting of these instruments are those designed to record the actions of the pilot in controlling the airplane. Many of the controlling operations of the pilot are very nearly automatic in about the same way as are those of an expert automobile driver threading his way through congested traffic. They consist of a series of slight movements of the steering wheel, light pressure on the accelerator, and possibly a shift of the brake, all of these being instantaneous reflexes to the state of traffic ahead as viewed at each succeeding moment by the driver. The airplane pilot "feels" his machine, and by slight movements of the control elements keeps it on the desired course. Not every pilot controls his machine in the same way, since not all have the same quickness of reflex or the same "feel" of the machine.

A new instrument has been developed called a control position recorder, by means of which every movement of the "joystick" is recorded and timed. This is not all, however, because in addition to recording what has actually been done, it is necessary, in order to judge of the controllability of an airplane, to know how much of an effort a pilot has had to exert to obtain a given result. This again can now be recorded and timed by means of a control force recorder, the two instruments together giving a complete record of what the pilot has done.

The next problem was to find out to what extent the airplane responded to the control operations of the pilot—whether it made the turns, dives, "zooms," etc., demanded of it, and how rapidly it did so. For this purpose an interesting series of instruments were developed. These are shown in Figs. 7 to 11, and the stability of an airplane, its ability to take turns, to accelerate, etc., is, or rather may be, recorded synchronously with the "position" and "force" records of the control apparatus. A comparison of the two records will show exactly and independently of any personal element of the test pilot just what had to be done to keep the airplane on its prescribed course and what its ability was to stay on that course and to respond to such changes as might be demanded of it. In this way it now becomes possible to obtain what may be called an index number of the controllability and maneuverability of an airplane, which enables one to compare two given machines fairly, reliably, and intelligently—something which has never been done before and cannot be done without a set of instruments of the type developed by the Committee.

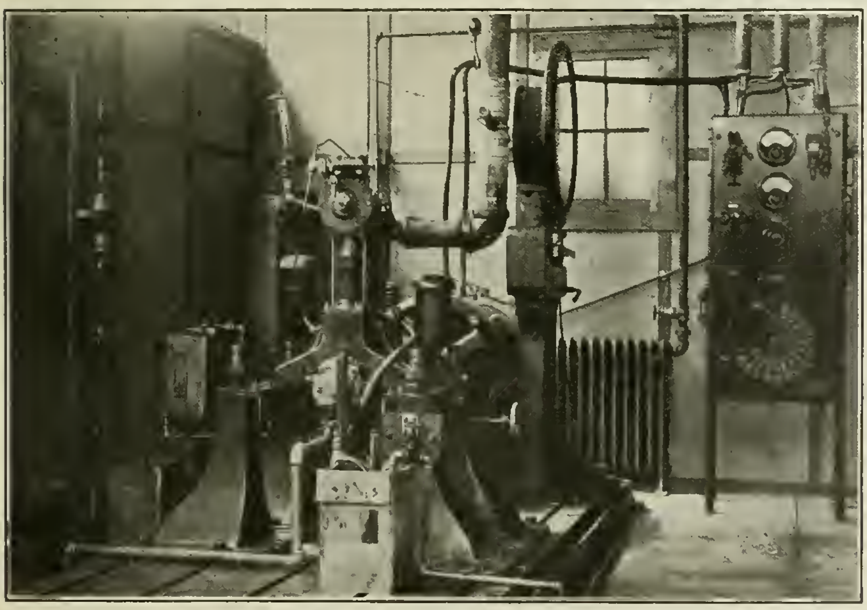

Fig. 15 General Set-Up for Testing a Liberty Single-Cylinder Special Unit When Operating on Fuel Injection and Autoginition

Test Airplanes

In this connection it may be mentioned that at the Langley Field research laboratory the Committee maintains a rather interesting assortment of airplanes. There are thirteen machines of ten different types ranging from single-seat Bee Line racers capable of making better than 180 m.p.h. to a huge torpedo carrier that looks like an aerial truck and carries about as heavy loads. The Committee has the services of two pilots, and it is the belief of the engineering personnel that work such as is done by the laboratory in the air should be performed by test pilots specially selected and trained for it rather than by ordinary flight pilots. The reason for this is that test pilots are more inclined to obey strict instructions as to what they should do than are ordinary flight pilots. Of course, when it is necessary to have extra machines in the air, arrangements are made to borrow the necessary personnel and equipment from either the Army or the Navy.

With thirteen machines in the hangar and extremely elementary facilities for handling the work, the laboratory manages to get along with two pilots and six mechanics in the hangar. In the two years that heavy flying has been done the laboratory has a record of close to 500 hr. in the air in all kinds of weather without a single smashup.

In addition to the flying work in heavier-than-air machines, which is practically all done at Langley Field, a certain amount of experimental work on lighter-than-air machines is performed at the Navy Base at Norfolk, Va. This is being done with the regular Navy personnel, the engineers of the National Advisory Committee for Aeronautics directing the actual tests and acting as observers.

Oil-Engine Design

One of the many problems that are interesting today every aeronautical power-plant engineer is that of the design of an oil engine for aircraft. The National Advisory Committee for Aeronautics is devoting a good deal of attention to this problem at its laboratory at Langley Field and is going about it in a way that is certain to result in greatly broadening our knowledge of medium-compression engines. This work is being carried forward in three directions. In the first place, tests are made on a dynamometer outfit with a single-cylinder Liberty engine, and while some interesting results have been obtained, a great handicap exists in the fact that this engine was not initially designed as an oil engine and, therefore, no matter how much it may be tinkered with, it will not give high efficiency as such.

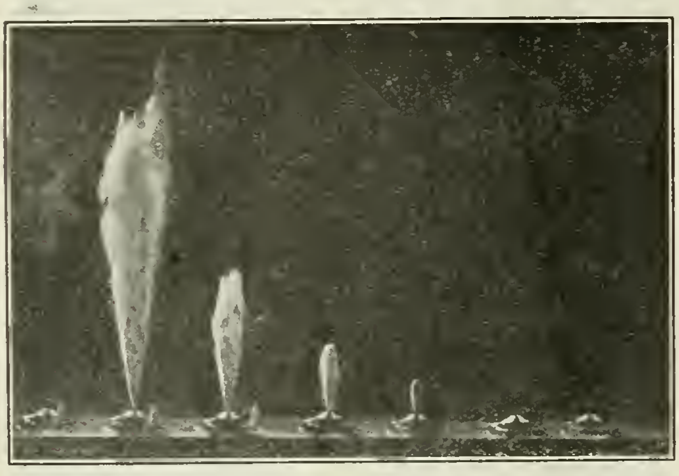

Fig. 17 Instantaneous Photographs of Fuel Sprays
(As noted in the text, these photographs were taken with an earlier type of apparatus and not with that shown in Fig. 16.)

From this point of view a good deal more may be expected from the unusual single-cylinder "universal" oil engine shown in Fig. 13. One of the features of this engine is that the compression ratio can be changed while the engine is running, as can also the timing and lift of both inlet and exhaust valves, as well as the fuel-injection characteristics.

This experimental work on actual engines is of course of great value, but after all so many variables enter into the operation of an engine that it is practically impossible to determine completely the influence of each one of them, and yet without taking them into consideration it is impossible to perfect a truly scientific design.

Because of this the laboratory undertook what appears to be a highly original research, namely, that of learning the behavior of various jets as affected by each of the several variables that enter into the determination of the character of the spray. Among these may be mentioned the shape and size of the nozzle, the pressure of the fuel, the temperature and viscosity of the fuel, the temperature and pressure of the gaseous medium into which the spray is injected, turbulence, etc.

The only practical way to investigate the various kinds of sprays appears to be by securing a photographic record of their gradual development. An apparatus (Fig. 16) was therefore built which made it possible to take photographs at the rate of 1350 per sec. Some of these photographs are shown in Fig. 17. Illumination for these photographs was provided by means of electric sparks, but in the initial installation the illumination proved to be insufficient to give the desired clarity of the pictorial image. The apparatus was therefore completely redesigned and is now practically completed. With it photographs may be secured at the rate of 5000 per sec., and the illumination has been increased so that it is now about tenfold what it was initially. From eight to twelve photographs may be taken during the period a jet is developing from its beginning to full size. It is easy to see what a light will be thrown on the process of jet formation by an accumulation of such photographs.

This, together with other developments at the research laboratory, may be taken as an indication of a determined tendency on the part of the Committee to organize its research so as to obtain data that will be as free as possible from errors introduced by the personality of the experimenter. In the case of jets this is done by photography, and in flight tests by means of the several recording instruments which tell exactly what the pilot and the airplane did. The behavior of the airplane itself is written down by kymograph, gyro turn indicator, single- or three-component accelerometers, gyro position recorder, angle-of-attack recorder, etc. To know by record and by measure is a good rule to follow, especially in a science as young and unorganized as aeronautics.

International Air Congress

THE following are brief extracts from two timely and informing addresses delivered before the International Air Congress held in June of this year in London on invitation of the British Government.

The Duke of Sutherland, who acted as Chairman of the Main Committee of the Congress, in delivering his inaugural address, said that the present time was full of great possibilities in the realm of aeronautics. We were on the eve of far-reaching advances in aviation, which might within the next decade or two bring about a partial or complete readjustment of our manner of living. To achieve the desired objects it was, however, essential that the results of research work and the experience derived from the Congress should be properly applied by means of the continued support of governments, and by the business initiative, and patriotism, of private citizens and companies of wealth and influence. The day had gone by when we could leave these things to develop themselves and work out their own salvation. The stakes were too great for us to stand negligently by, while the world's greatest secrets were almost within our grasp. The development of civil and commercial aviation between all countries on a scale hitherto unrealized and the evolution of a popular, cheap light airplane for the public use were both essential factors for the future, and were undoubtedly the forerunners of the world's entry into an aerial age.

J. D. North, in his address on The Technical Development of the Aeroplane, spoke as follows:

"Mechanical flight in the brief twenty years of its existence has passed through four phases, each of an approximately equal period, and which are defined sufficiently clearly to be marked by the observer. There are indications that we are now entering on a fifth phase in the art and practice of aviation, the trend of which forms a legitimate field for speculation.

"Let us take stock of our technical assets. We have a large amount of incompleted work which requires sifting and developing to its proper conclusion. We cannot expect to develop the aeroplane on the heroic lines, the achievement-at-any-price methods, which were proper to the war period. Probably we shall be compelled to concern ourselves mostly with small matters out of the multitude of which great things may come. First, there is the development of the aeroplane from the economic standpoint, the improvement of the ratio of the useful load to the gross weight, and the improvement of fineness whereby for given horsepower this gross weight may be given a better performance. These may be attacked either by systematic improvement of detail or more speculatively by radical changes in design." (*The Engineer*, June 29 and July 6, 1923, p. 682, and p. 5.)

The Port of Montreal

Factors Contributing to Its Development—The River St. Lawrence Ship Channel—Mechanical Handling in Montreal Harbor—Electrification of the Harbor Terminals—Floating Drydocks, Standard Piers, Etc.

By FREDERICK W. COWIE,[1] MONTREAL, QUEBEC

THE PORT OF MONTREAL is essentially a national port. It has been developed upon a national principle, namely, that of coöperating with production in its completest sense for marketing, for warehousing, for collecting, for manufacturing, and for shipping—the principle of a truly modern port.

The total land area of Canada is 3,600,000 square miles; the density of population is less than $2^1/_4$ per square mile as compared, for instance, with 30 per square mile in the United States. This vast area, the tremendous distances, and the distribution of the sparse population make the problem of transportation one of vital importance. Canada, with four times the present population, may produce, for export, one billion bushels of the finest wheat in the world.

The fundamental difficulties in the way of production and marketing in Canada are population, climate, and distance. From the center of production in the Canadian Northwest, in the vicinity of Moose Jaw, or Saskatoon, the transportation distance, by rail and water, to Montreal is over two thousand miles. Further, there is also the desire on the part of the farmer to market his products before the winter sets in, when the Great Lakes and St. Lawrence routes are closed. The transportation problem, therefore, is a serious one, and one of the factors in connection with that problem is the port terminal.

The development by Canada of navigation on the St. Lawrence, reaching a thousand miles into the interior of the continent; the development of the port of Montreal; and the improved canal navigation between Montreal and the head of the lakes, have been recognized as national necessities and have been promptly carried out to the credit of, and by the credit of, Canada. For a young country with such a small population and limited financial resources, the record is respectfully submitted as being a most excellent one. Not long ago a writer in *Collier's Weekly* summed up matters as follows:

> Within the past decade Canadian enterprise has been building at Montreal one of the most modern and efficient harbors in all the world. Yet the harbor of Montreal is a thousand miles from the sea, and for five months of the year is closed by ice. It has always struck us that the development of the port of Montreal is one of the most daring and sportsmanlike pieces of commercial enterprise that ever has come before our eyes.

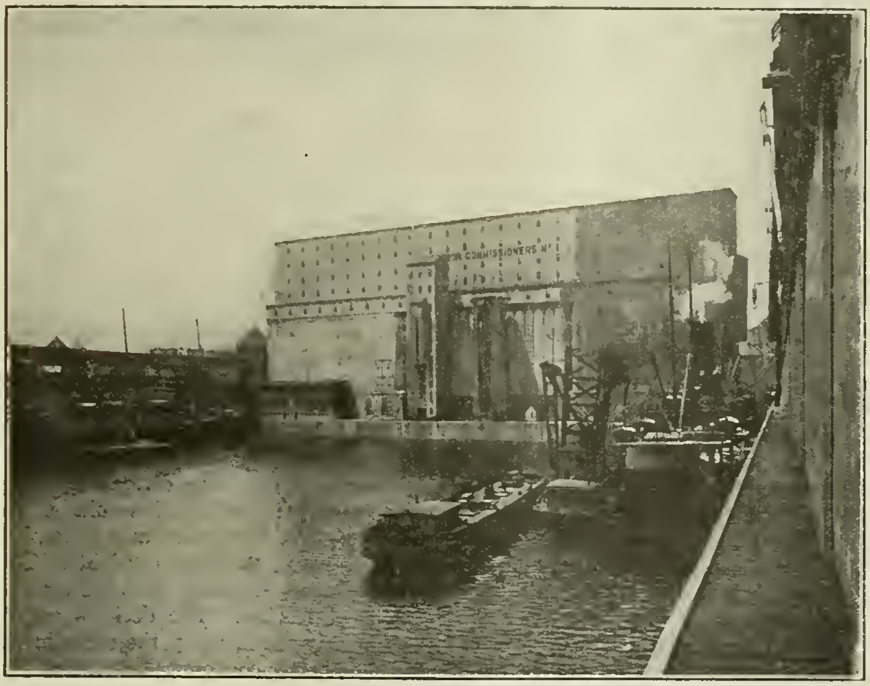

Fig. 1 Harbor Commissioners' Grain Elevator No. 1
(Storage capacity, 4,000,000 bushels.)

Factors Contributing to the Development of the Harbor of Montreal

One hundred years ago the city of Montreal had a population of less than 20,000. Quebec was the great Canadian St. Lawrence seaport, and the depth of water in the channel to Montreal was, during the low-water season, only 11 ft. The total ocean freights by ship, to and from Montreal, one hundred years ago could have been carried in one of the several modern ocean steamships which may be seen in Montreal today.

There were then no railroads, and no canals. As the brig of 250 tons represented ocean navigation in Montreal, so the batteau, a flat-bottomed boat, pointed bow and stern, 35 to 40 ft. long, the usual freight being from four to five tons, represented the entire system of transportation to a rapidly developing Ontario, then called Upper Canada or Canada West, as well as to a large section of the United States bordering on the Great Lakes.

In the meantime, while the two provinces, Upper and Lower Canada, could not agree upon financial arrangements, the enterprising citizens of the United States discovered that remarkable pass, the Mohawk Valley, through the Alleghenies, and built their own "St. Lawrence" from Buffalo to the Hudson River, opening it in 1825, one year before Canada opened her first Lachine Canal.

The first Lachine Canal was opened in 1826. Its locks of masonry construction, remarkable at that time, were $6^1/_2$ ft. wide, and had a depth over the sills of $4^1/_2$ ft. They were specially constructed for navigation by Durham boats, vessels of 20 to 30 tons. In the meantime Montreal became the point of transfer between ocean navigation and inland transportation, and has retained that position now for one hundred years.

The first harbor commission having in view the improvement and development of the port of Montreal was established in 1830. Montreal at that time had just emerged from being a walled town, and the only port accommodation consisted of the beach extending from the river wall to the water. There were originally five gates from the river to the town, but with the introduction of the river steamer in 1812 from Quebec, and the necessity of more economy in discharging the brigs of that day, wharves were required.

The new harbor commissioners having before them only a sketch plan, decided with wisdom upon obtaining the advice of that eminent civil and mechanical engineer, Peter Flemming, of Albany, N. Y., who had just achieved fame by the successful completion of the locks of the Erie Canal.

Peter Flemming's first report outlined the difficulties, and suggested wharf structures estimated to cost £39,000. He recommended rock quay walls, and his estimate was based upon this type

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[1] Consulting engineer, Harbor Commissioners of Montreal. Mem. Eng. Inst. of Canada.

Contributed by the Materials Handling Division and presented at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, of The American Society of Mechanical Engineers. Abridged. All papers are subject to revision.

of structure. Another engineer, whose name has not lived in history, suggested a timber-piling type of structure, and as this was found to save £10,000 it was adopted. Unfortunately, however, when the spring ice shoves swept down upon this timber structure, the inevitable happened.

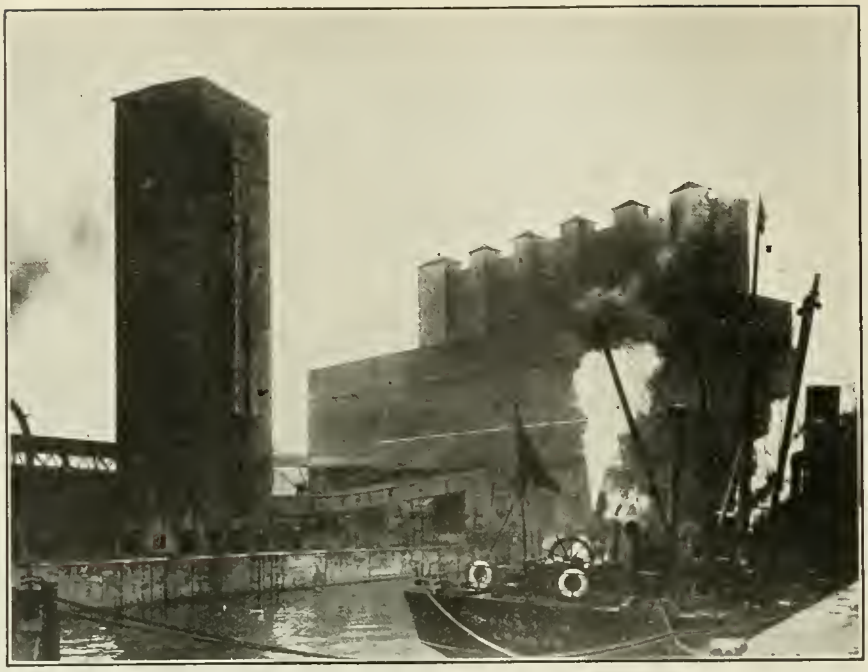

Fig. 2 Harbor Commissioners' Grain Elevator No. 2
(Storage capacity, 2,622,000 bushels.)

The River St. Lawrence Ship Channel

It was the genius of the mechanical engineer that made possible that great achievement, the River St. Lawrence ship channel from Montreal to the sea.

The first dredge was built in Montreal in 1838, the machinery having been brought from Scotland. From 1840 to 1844 various preliminary works—experimental and otherwise—were carried out, and it was only in 1840 that actual progress was commenced. The author was first identified with this great work in 1886 when it was considered a wonderful and successful enterprise.

Two types of dredge were then in use, the elevator dredge and the dipper dredge. It was soon apparent that the latter, though effective, could not coördinate with continuous navigation, and the elevator dredge, floating and held in position by "crab" moorings so that it could quickly haul itself out of the way of passing ships, was adopted.

From Montreal to Murray Bay the total distance by river is 220 miles. In this distance dredging for deepening the natural channel has been required over a distance of more than 70 miles.

Fortunately, owing to the settling basins, the Great Lakes, there is practically no sediment in St. Lawrence water, so that the dredged channel once completed remains permanent. The material varies from a soft blue clay of the consistency of a cream cheese to hard shale rock, almost as hard as ledge limestone. The quantity of material dredged has nearly reached the enormous total of 100,000,000 cu. yd.

It was at Montreal that the elevator dredge was first adapted to dredge shale rock; immense cast-steel buckets with forged special steel teeth, operated by the necessarily powerful machinery, were successfully designed to dredge this hard rock at a depth of 48 ft. in a strong current; and to carry on at a rate of 2500 cu. yd. per day, working day and night; at a cost of 40 to 50 cents per cu. yd.

Immense boulders covering the bed of the river, many of them weighing 50 tons, had to be lifted and removed; all of which was successfully accomplished without blasting.

In Lake St. Peter, where the depth had been originally 11 ft., 18 miles of solid dredging was required. For this work several types of dredges were designed. The late Sir John Kennedy, a mechanical genius, improved the ladder dredges to such an extent that one dredge vessel was capable of dredging and having removed by scows 6000 cu. yd. per day at a cost of 3 cents per cu. yd.

When the project for widening and deepening the channel was undertaken in 1900 under the direction of the author, it was evident that a new departure was required for speed as well as economy. The suction dredge was investigated, but it was found quite impracticable to pump the sticky blue clay of Lake St. Peter by the suction principle. Mr. A. W. Robinson, Mem. A.S.M.E., a mechanical engineer of Montreal was consulted, with the result that the dredge *J. Israel Tarte* was designed, constructed, and put into operation. This dredge, having a rotary cutter and working on the suction plan, was capable of dredging and removing by pipe the mud of Lake St. Peter at the rate of 12,000 to 20,000 cu. yd. per day.

The cross-section of the 8-mile Culebra Cut of the Panama Canal was originally designed at 8000 sq. ft. The cross-section of the St. Lawrence in the three miles of rock cut is 80,000 sq. ft.

The Port of Montreal

Montreal Harbor today represents a capital cost of $35,500,000. It is hard to believe that the sixth port in the world, or the second in America, could have been developed, including harbor dredging; wharves, piers and basins; warehouses; grain elevators and equipment; real estate; railways and electrification; permanent sheds; with all plant and equipment, at such a modest price. Port authorities throughout the world may obtain much valuable information by analyzing the principles and methods adopted by the Montreal Harbor Commissioners and which have resulted in such an almost unparalled achievement.

Mechanical Handling in Montreal Harbor

It is admitted that only such mechanical handling has been adopted in Montreal Harbor as has been found absolutely necessary and as has been demonstrated to be desirable and economical.

Some years ago, by the direction of the Harbor Commissioners of Montreal, an exhaustive study was made of harbor freight-handling devices by several eminent engineers. These men unanimously agreed that it would be unwise to equip the Montreal docks at that time with any general system of freight-handling devices, except for special freights. The "forest" of cranes which is in evidence in many European ports is therefore not seen in Montreal Harbor. The decision regarding mechanical handling was greatly modified by the recommendations of the author that equal or better economical results could be obtained in the harbor by special correlation between the railways and the docks, the concentration and use to full capacity of facilities, and the extension of the grain-elevator system of delivery of grain to all berths in the central harbor.

Electric hoists were designed, for the first time, to make equally valuable the upper as well as the lower stories of the transit sheds. This design, so very successful, was adopted when team transporting was the rule. At the present time when motor-truck transport is feasible on an 8 per cent grade, there is room for difference of opinion. Practically the whole of the Montreal Harbor system of transit sheds, having a total floor area of 60 acres, is specially well adapted for the use of the storage-battery truck and trailer, and for the new system becoming so general in American ports, namely, the supporting warehouse.

For general cargo, therefore, as may be seen by actual demonstration, Montreal Harbor is sufficiently equipped, in coördination with the splendid freight equipment of the ships, for speedily, economically, and with great satisfaction to all concerned, turning around ships and their cargoes.

Special Freight Handling. While there is satisfactory equipment for the handling of coal in the harbor, Montreal is not an outstanding coal port.

The handling of live cattle is conducted with great rapidity and satisfaction from railway cars through the sheds to the gangways

of the ships, without any special equipment and without requiring the ships to move from their berths.

For the storage and handling of flour special facilities have been under consideration, and it is expected that this feature will require similar study and similar accomplishment as exemplified by the design and installation of facilities for the storage and handling of grain.

The Storage and Mechanical Handling of Grain. In America the areas of export production are at a great distance from the seaboard. Grain has to be transported over great distances and handled many times as compared with the producing areas in competing countries. Moreover it is difficult to realize the magnitude of the quantities of grain produced in America. In North America the production of grain annually is in excess of six billion bushels. At least five hundred million bushels are exported, and, let us say, three hundred million more are shipped to some local market, the remainder—two and a half billion bushels—being consumed on the farm.

In America, as a rule, export grain is handled at a country elevator, at the head of the lakes, at a lower lake port, at an ocean port, at a port in Europe, and at the final milling point. The cost of this handling for the export business may be estimated at 8 cents per bushel and amounts to $40,000,000 annually. The three billion bushels of local grain are handled at least twice, at an estimated cost of, say, 2 cents per bushel; a further amount of $60,000,000 annually. That is, the cost of handling the grain grown in America amounts to something like $100,000,000 annually. What a prize if the cost could be decreased 25 per cent, or even 10 per cent!

The port of Montreal is one of important handling ports for export grain in America and last year handled over 155 million bushels. Without the grain business and profits on handling, Montreal would not be the second port in America.

When it is considered that on the opening of the Canadian Pacific Railway in the West in 1886 there were no facilities and no organization of any kind for the handling of grain, one is profoundly impressed with the successful mechanical development which has resulted in the handling of the present production with one-sixth of the Canadian Northwest agriculturally developed; and with the requirements of the future, when five-sixths will be sending their streams of export to the markets of the world.

It may be asked, "Is there anything left in the way of possible improvements?" But when it is considered that grain may be received, weighed, stored, reweighed, and delivered to a ship at her berth half a mile from the elevator at about 50 cents a ton, why not rest satisfied?

During the war, when labor was so scarce and shipments required to be urgent, it was found almost impossible to unload promptly the railway cars containing grain into the elevators. The author accordingly undertook an investigation into the possibility of the mechanical unloading or dumping of cars. This investigation was later continued by the John S. Metcalfe, Co., Ltd., of Montreal and Chicago, who finally succeeded in designing a grain-car dumper which has solved the problems of labor, time, and cost in a most satisfactory manner.

When it is considered that the old method of unloading grain cars by shoveling required from four to five men for half an hour, while, with the new dumper, it takes a similar gang only six minutes, its value will be appreciated. A feature of the car is that it may be installed in a separate building, thus greatly minimizing the danger from dust explosions.

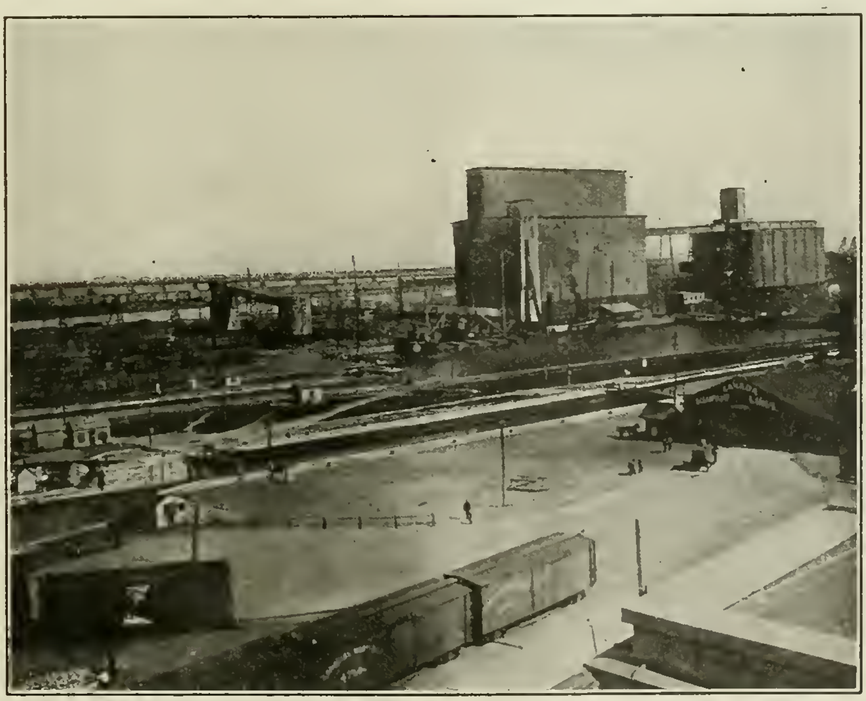

Fig. 3 Grand Trunk Railway Grain Elevator
(Showing in foreground locks at entrance to Lachine Canal; storage capacity, 2,100,000 bushels.)

There remain, however, serious problems requiring solution, such as the trimming and shoveling of grain in vessels in America, and particularly in the European ports.

The Mechanical Handling of Flour. As wheat unmanufactured is exported in great quantities, so manufactured wheat or flour is now becoming a very important item of American commerce. Who can solve the problem of a "container" more rapidly transportable and economical of space than the barrel and less wasteful and better than the sack, and thus make flour shipment compete with that of bulk wheat?

The Cold-Storage Warehouse. Last year there was opened for business in the harbor of Montreal a cold-storage warehouse, which was built to aid the producer in the preservation and marketing of his products and to lengthen the season for the consumer for many articles of daily consumption. This first example of this phase of harbor development is only a beginning, and modern ports are in many cases now considering this type of harbor enterprise.

Electrification of the Harbor Terminals

The Montreal Harbor railway terminals consist of surface lines situated between Victoria Bridge and the Imperial Oil Wharf, a distance of 10 miles, and have a total trackage of over sixty miles.

For several years nine standard locomotives have been in operation. Recently, however, it appeared that if the service was to be maintained to its highest efficiency, additional locomotives would be required to maintain a prompt service.

After investigation and study, electrification has been found to be not only economical but more efficient than the use of steam locomotives, especially during the winter months, the price of coal having in recent years advanced 300 per cent as against an increase of only 8 per cent for hydroelectric power. Further, through the Canadian National Railways' electrified terminal the Harbor Commissioners have a marginal harbor railway terminal connecting all railways and all plants on the river front with the harbor docks.

Floating Drydocks

Opposite Maisonneuve a tract of land 30 acres in extent was reclaimed from the harbor and leased to Canadian Vickers, Ltd. A shipbuilding and repairing plant was installed here and the floating dock *Duke of Connaught*, built in England, was towed to the same location from across the ocean. This drydock is capable of accommodating the largest existing vessel of the British Navy and has the following dimensions:

- Length, 600 ft.
- Width, 135 ft.
- Length of side walls, 470 ft. 6 in.
- Height of side walls, 59 ft.
- Draft of vessel for dock, 30 ft.
- Lifting capacity, 25,000 tons

Standard Piers in Montreal Harbor

A standard pier in Montreal Harbor is 1200 ft. long and 300 ft. wide. The interior filling of the pier is solid, so that the ground-floor or pier cargo weights are not limited.

The pier area is laid out with one standard railway track on the quay front. Closely adjoining this track there

is a two-story transit shed 100 ft. wide and 500 to 600 ft. long, built of steel and concrete and fireproof throughout. The lower floor is elevated to the height of a freight-car platform.

In the pier center, adjoining the shed, there is a 6-ft. trucking platform, two standard railway tracks, and a roadway. For the inner sheds and also for the outer sheds there is a vehicular elevator. These elevators carry two trucks at a time up to the upper-story level, and at each elevator a transverse bridge connects with the two sheds.

The marginal railway required to feed this pier, assuming shunts to be made every six hours, day and night, has been found to necessitate two standing tracks for waiting cars, two through-running tracks, and two other tracks partially for waiting cars and partially for teaming, the length required for each pier being at least 1000 ft. This is in addition to the holding yards at various points in the terminals.

The upper stories of the transit shed are designed to carry a floor weight of 600 lb. per sq. ft. They are used almost entirely for imports, but also to some extent as collecting warehouses for export freights.

Grain is delivered to these berths from overhead conveyors entirely separate from other cargoes. Ships may receive grain from two belts at a time at the rate of 15,000 bushels per hour each, the grain being spouted directly from the belt into the hold under a head, which with goosenecks eliminates to a great extent trimming in the vessel. Outside of the ship there is ample room for lighterage.

The four berths at each of these piers are designed after long experience for American traffic, and are based on each berth being able to unload an average cargo of 5000 to 6000 tons, and load an average of 8000 to 12,000 tons per week. These berths are used to capacity throughout the season of over seven months.

The St. Lawrence Deep Waterway

For many years the organization known as the Harbor Commissioners of Montreal has been recognized generally as a public trust. Important public interests relating to navigation, to the St. Lawrence route, to maritime commerce, as well as to the harbor of Montreal have been entrusted to them, not only for development but for guarding inviolate the rights, obligations, and interests of Canada in the River St. Lawrence district.

The commissioners have declared officially that their policy must be commercial development; their duty, to guard and improve navigation. They submitted for the consideration of the International Joint Commission their opinion that approval of every important project connected with the St. Lawrence should be withheld until a properly developed plan has been prepared, taking in the whole river from Lake Ontario to Montreal, that will fully safeguard for the people of the United States and Canada their heritage in connection with:

1 Navigation
2 Hydroelectric power
3 Regulation and flow.

Why, it may be asked, is the St. Lawrence deep-waterway project more acutely before the public today than it was ten years ago? Ten years ago steam coal was available in Ontario and Quebec at $3 per ton, and the supply was ample. Today the price is two and a half or even three times higher and the supply unreliable. Ten years ago the price of transportation of a bushel of wheat from the farm to the United Kingdom market was 15 cents. Today it is double that.

Before the war Canada was not the equal of other countries as regarded engineering and industrial works and variety of industrial output. Today, however, she can build any or all of the parts needed in hydraulic and electric developments, and much that was not known ten years ago about ice control and low-head power has been learned and successfully applied in practice.

What equal project in the world, therefore, now offers an equal return to man from the generous resources of nature?

For navigation purposes alone the St. Lawrence deep waterway may be admitted as of doubtful economy. The Harbor Commissioners of Montreal, however, representing not merely the interests of Montreal but of all Canada, have taken an eminently fair attitude upon this question. In their excellent annual reports they have stated that they do not believe that ocean vessels, except specials, are either fitted for inland navigation or can compete with the Great Lakes type of vessel, including a transfer at Montreal.

They would welcome and have reserved harbor accommodation for the 10,000-ton lake vessel, but they specifically state that, in their view, public money at the present time, if available, will yield better returns if applied to improving proper port terminals.

Navigation improvements and the development of hydroelectric power may come hand in hand. The latter may pay for the former. But before such a scheme may be considered, it should have, and it is worthy of, the most profound consideration and the most careful investigation.

A Montreal Bridge Project

Seventy years ago, when railroad transport had proved its success, a bridge was projected and later built to carry railway trains across the St. Lawrence. Today it is a question of the requirements of a bridge for motor transport.

In 1919 the limits of Montreal Harbor, placed by the Canadian Government under the jurisdiction, control, and management of the Montreal Harbor Commissioners, were extended to include the beach and bank of the south shore of the River St. Lawrence to high water mark, and to include both sides of the river down as far as Bout de l'Ile. The object of this enlargement was the coordination of all units of harbor development into one scheme.

A Montreal bridge scheme, and there are several, with its possibilities for industrial developments, its harbor connections, its possible connection with the island and the south shore and its location so near the center of the City of Montreal, offers attractive possibilities. The Harbor Commissioners' construction work and administration have received the approval of the public, and taking the point of view of navigation and other administrative requirements, it is believed that they could operate this bridge in the public interest.

Discussion

In the discussion which followed the presentation of the paper the author, replying to a question asked by W. S. Jacobs[1] regarding the unsuitability of ocean vessels for inland-waterway and lake transportation, said that ocean ships were built at very great cost, with very great strength, and with special features for safety. The result was that they had very small rudders and in going into ports, docks, locks and narrow channels, tugs were invariably required. On the other hand, the lake vessel was built very cheaply, with small engine power, a flat bottom, and no keel, but with a tremendously large rudder. The result was that it could go into the Chicago River, the Buffalo River, or any lock in the country without a tug. The cost of construction and operation of the ocean vessel was so high as compared with the lake ship that it was considered that the lake ship could handle the bulk type of cargo that originated in the territory between the head of the lakes and Montreal or some other port where it would be transferred to the ocean vessel, cheaper than if it was carried all the way by ocean vessel.

In reply to a question asked by Augustus Smith[2] as to whether the port charges for the wharf service and for elevator service were sufficient to defray the interest charges and operating charges of the magnificent structures he had described, or whether any portion of such expenses had to be borne by taxation, the author said that the Harbor Commission of Montreal had been in existence for almost one hundred years and had never failed to meet all interest charges and all cost of operation, and that usually they had a tidy surplus. The Commission could always get their projects put through, in spite of the financial situation of Canada, the reason being that Montreal Harbor paid so well and had been found so essential to the requirements of production and industry. In 1906, the year after he had been appointed chief engineer of the Commission, the total gross revenue was less than $450,000 and the total debt almost $14,000,000, nearly half of what it was now. At present the gross revenue was $3,500,000.

[1] Treas., Walton Co., Hartford, Conn. Mem. A.S.M.E.
[2] Pres., Bergen Point Iron Wks., Bayonne, N. J. Mem. A.S.M.E.

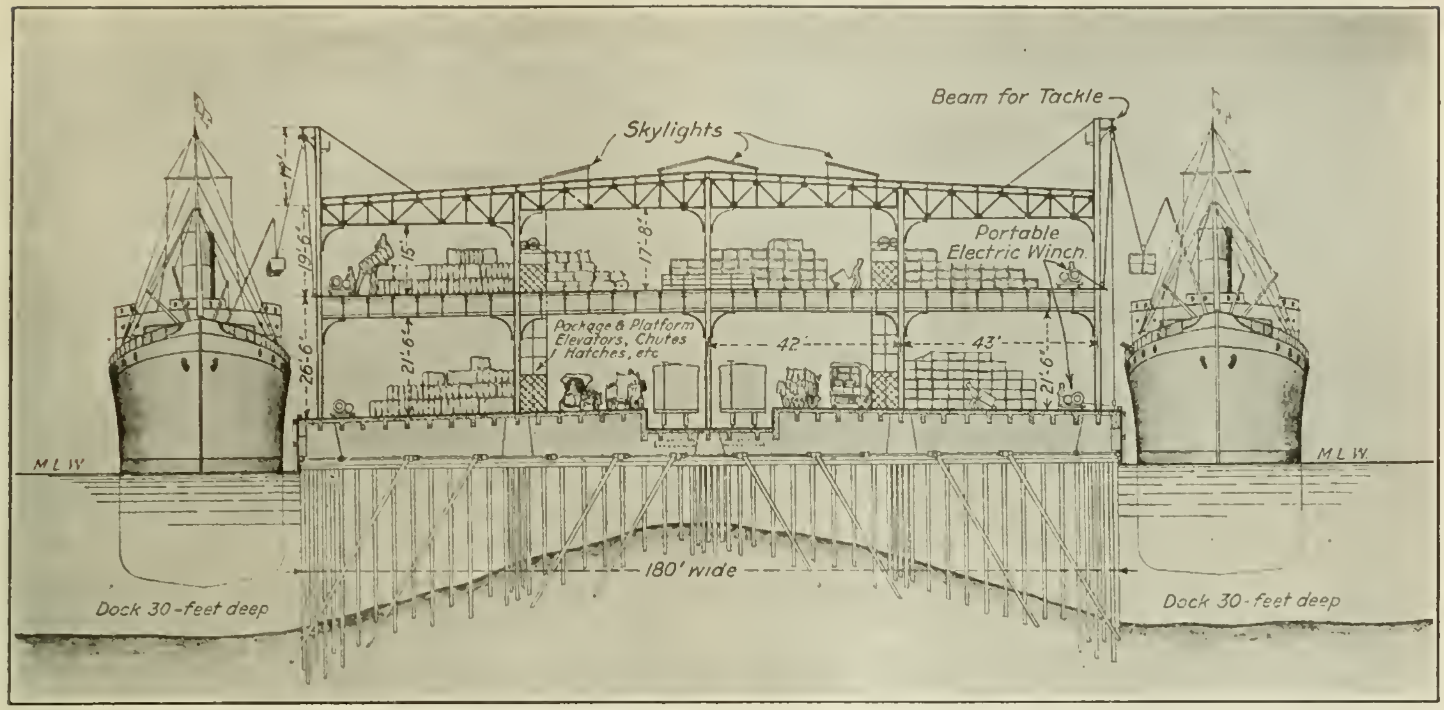

Fig. 1 Typical Cross-Section of Municipal Piers Nos. 38 and 40, South Wharves, Philadelphia

Material-Handling Problems in Pier Design

A Review of the Proceedings of Several Material-Handling Symposiums Held by The A.S.M.E. To Discuss Material-Handling in Its Relation to Port Development

By CARROLL R. THOMPSON,[1] PHILADELPHIA, PA.

TWO very important factors influencing the plans and policy of improvement and development of our ports which seem to preclude the possibility of substantial standardization of harbor facilities, are

1 The control and operation of the port facilities, and

2 The local conditions of the port.

both of which have a direct bearing upon the character and amount of freight-handling equipment that are justifiable on the pier or wharf.

No material-handling problem is more complex than that of the transferring of freight between land and water carriers at the pier. It is also one that requires diverse consideration of every element involved in the functions of a port, and as these transfer operations center at the pier, the importance of its proper design, layout, and equipment cannot be overstressed.

Control and Operation

In some of our ports where the port administration body owns and operates the facilities there is a greater tendency to experiment with and develop equipment than where the freight movement is entirely in the hands of the pier operators. There is no hesitancy in equipping the facilities with labor-saving devices. The cargo-handling problem is under the direct control of the harbor commission. Accounts, cost data, efficiency records, and maintenance are under constant observation. Inefficiencies can be immediately corrected, whether they be due to faulty equipment or to lack of proper coördination.

At most of our older ports, railroad and private ownership and operation of facilities is more extensive than public ownership, and the handling of freight through the terminals is generally done by shipping companies or stevedoring organizations. The publicly owned facilities are usually leased to private concerns and the *direct* control of freight handling is therefore not under the supervision of the port authority, which would naturally hesitate to equip its facilities with many forms of cargo-handling devices of doubtful efficiency, believing the installations, particularly equipment of the portable type, to be a matter for the operating companies. A harbor authority cannot afford to invest money in freight-handling machinery that may not be used—unless as a means of advertising the port to attract new business. Then again, this policy of port administration brings up the question of responsibility for the maintenance of the publicly owned equipment—which is subject to more or less abuse. Pier operators in their eagerness to turn around a ship in the least possible time often resort to "emergency" repairs in order to speedily overcome a breakdown and put the apparatus in operation while ship loading is under way; and these so-called "emergency" repairs are frequently made by unskilled mechanics who have a very limited knowledge of the construction and design of the apparatus, with the result that more damage is caused and later on serious trouble is encountered and complete overhauling may be necessary. Disputes naturally arise between the tenant and the landlord over the question of responsibility. With public operation this difficulty is eliminated and proper maintenance can be assured.

Some of our port authorities also have functioned very successfully under a policy of constructing pier facilities to attract commerce. In such a policy, however, the specific character of business that may come to the pier cannot be anticipated previous to its construction, and there is the possibility of installing apparatus not adapted to meet such problems of freight handling as may ultimately arise. Under present-day conditions, steamship lines will not wait until pier facilities are built for their particular accommodation but will seek the ports that already have them. A port-authority problem becomes more complicated in attempting to build piers to suit any steamship company's business, and port authorities properly hesitate to expend large sums for extensive

[1] Asst. Director, Department of Wharves, Docks and Ferries, Philadelphia, Pa.

Contributed by the Materials Handling Division and presented at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, of The American Society of Mechanical Engineers. Abridged. All papers are subject to revision.

freight-handling machinery that may remain idle and in the last analysis prove to be a handicap and burden rather than an asset.

Local Conditions

Undoubtedly the most important consideration which enters into the general layout of a port and its freight-handling facilities is the rail and inland-waterway service. One port may be free from the lighterage problem, or comparatively so, while at another it may be practically the only means of interchange between railroad car and steamship. The freight-handling problems of two such ports would therefore differ. In the one case transfer of freight between car and ship is confined almost solely within the pier; in the other a considerable amount of freight would not come in contact with the pier facilities, transfer being made direct between ship and lighter. With the inland waterway service, the port facilities must of necessity be equipped for loading or unloading barges, which do not as a rule carry freight equipment.

Trade in bulk commodities may be the principal commerce of some ports—they may have been developed especially for trade in grain or other bulk cargoes such as coal and ore. The material-handling proposition for such commodities demands that facilities be designed for a particular trade.

Coastwise trade requires a different terminal design from that for foreign trade. The loading or unloading of freight through the side ports of coastwise ships is an entirely different proposition than loading transoceanic ships over the side through deck hatches. Tidal conditions of a port are a very important factor in the design of a pier to be used by "side port" ships; wharf drops or movable gangways are essential for loading operations at all stages of the tide. In coastwise trade a great amount of local freight is brought to the pier by teams and motor trucks—the transportation units that cause the greatest amount of confusion and congestion in pier sheds. The upper story of a two-deck pier shed would be useless for a coastwise terminal operating with side-port ships.

The character of the intercoastal commerce also influences the design. Local deliveries by team and motor truck are very important factors in this trade.

Some ports may be developing for all three of the principal trades—the foreign, coastwise and intercoastal. It is entirely feasible to construct a general cargo pier that will admirably serve any of these trades, although there would be features incorporated in the design of such a combination structure that would prove useless for some of the trades. For example, wharf drops, which are necessary for the coastwise ships, would not be used by transatlantic ships. The upper story of a two-deck pier, which is essential in some ports for the foreign trade, would not be of service in the coastwise trade. A depressed wagonway would be of great advantage on a wide pier for either the coastwise or intercoastal business, while the space it occupies might be used to better advantage for cargo area in some of the foreign trades. Wharf cranes might prove to be valuable equipment for loading export freight but a great disadvantage on a pier used in the coastwise trade owing to the space they would occupy.

It would seem, then, that no one ideal plan of improvement would be feasible for every port and that each port must solve its own problem to satisfactorily meet its own conditions, taking all elements into account.

In speaking of What Constitutes a Modern Port, the late B. F. Cresson, Jr., also considered the effect of local conditions upon the railroad service and pier layouts in the following statements:

> Where railroad cars can be brought direct to the ship's side, piers should generally be built considerably wider than when the service must depend upon lighterage movement between the railroads and ships.
>
> Where there is plenty of undeveloped land it is believed that for economy the initial development should be of the quay type, looking forward to piers if the demands of commerce increase beyond the capacity of the terminal under quay development.

Mr. Cresson also suggested zoning by trade routes as a solution to overcome the disadvantages of equipping piers to accommodate any of the general cargo trades.

Bulk Cargoes

Bulk cargo, such as grain, ore, coal, etc., does not present as complicated a problem in handling as the great variety of commodities which form general cargo. Equipment for this class of cargo has been developed to a very high degree of efficiency. Generally shipments are made in full cargo lots and the equipment can be designed exclusively for loading, unloading, or the storage of a uniform product, which greatly simplifies this particular phase of the material-handling problem. Also, such commodities are invariably handled at piers equipped and built especially for the purpose.

Miscellaneous Cargo

The problem of efficiently and economically handling miscellaneous freight or general cargo over piers is the most difficult to satisfactorily solve of any of our port problems; it is most complex and one that demands the utmost flexibility of freight movement. It also requires the introduction of mechanical equipment.

In dealing with the subject of freight-handling machinery on the pier, it must be constantly borne in mind that while the general cargo shed is only a single unit in port-terminal operation, it must be designed to function properly with every other port facility. Coördination of the port's various facilities must be adhered to. Proper conception of the duties of the general cargo pier must not be lost sight of. For quick dispatch of freight between land and water carriers with the many attendent problems in connection with cargo, the wharf should not be permitted to perform ware-

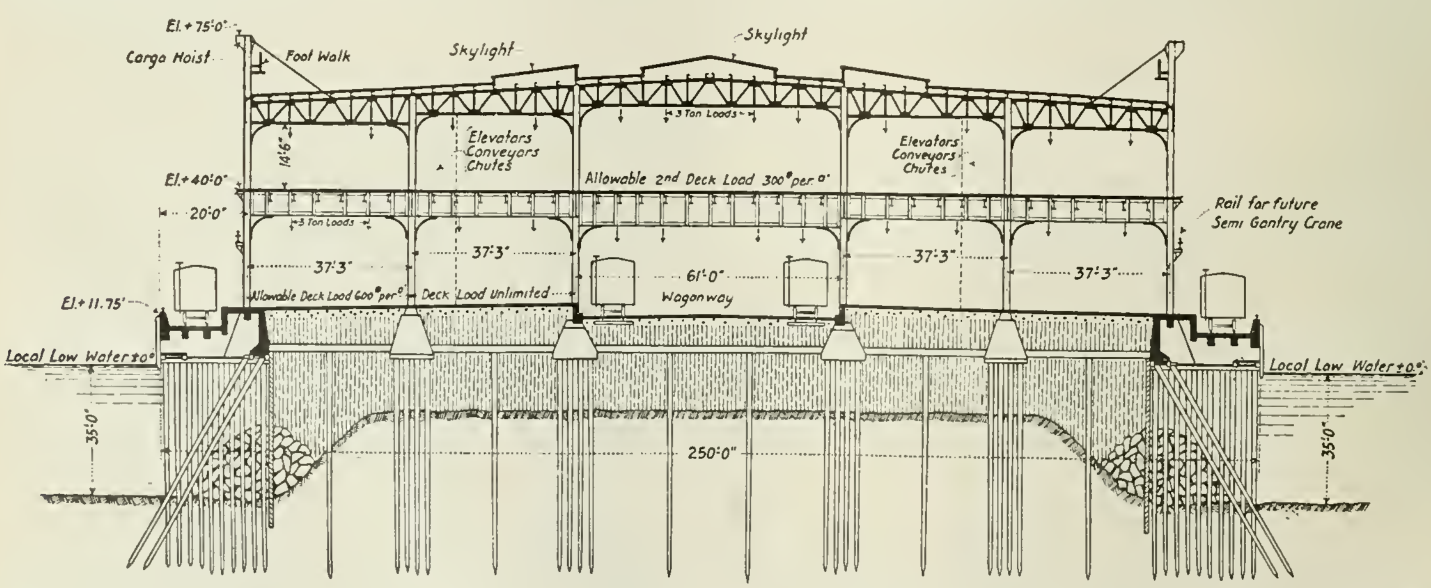

Fig. 2 Typical Cross-Section of Municipal Pier No. 78, South Wharves, Philadelphia, Showing Depressed Apron Tracks, Depressed Center Tracks and Wagonway; Also Provision for Future Installation of Semi-Gantry Cranes

house duties; that is another phase of the general port problem, and while of very great importance to the successful operation of any port, should be treated as a separate unit and coördinated with the pier as well as other facilities.

General cargo comes to the pier shed in many varieties of forms, sizes, and weights, and packed in all sorts of containers, to or from a multitude of consignees and shippers, and over any of the transportation systems entering the port. The first essential purpose of the shed is to provide ample, unobstructed cargo deck space—protected from the elements—for the sorting and assembling of this cargo for delivery to the ship, or to the railroad car or motor truck for removal. General cargo must be spread out on the pier: it must be sorted, classified, checked and weighed, and arranged for proper sequence of loading.

The run in and out of a ship for a few hours may be bagged stuff, the next run of cargo may be boxes or cases that weigh a ton, and then again in the same hold of the ship there may be a class of freight measuring a foot or two in diameter and ten or twelve feet in length, and so on. In loading cargo the various consignments from a great number of shippers must be kept separate, while import cargo must be handled in a specific manner for customs weighing and inspection. This further complicates the problem.

In modern pier operation it is impracticable to tier goods to any great height. Dr. R. S. MacElwee has pointed out that for short-time storage it is not economical to pile above five feet high.

Ample deck area is the first essential for a modern-day pier. In addition to the space required for cargo purposes, space is also needed for railroad tracks—which in a modern port are as necessary to the pier as the berth for the steamship—and considering the importance of freight delivery by motor truck and team, additional width of pier should be provided for that purpose. Adequate space for handling all of the operations connected with general cargo is a prime factor in reducing congestion—the most serious cause of delay and expensive handling cost.

Every effort should be used to eliminate obstructions to the free movement of freight. Where columns are required for the support of the shed structure, the number should be reduced to a minimum. The location of any stationary freight-handling equipment should be carefully considered, with the view of permitting the utmost flexibility of freight movement.

Unless the wide-pier terminal with ample, unobstructed cargo decks is constructed, the handling of cargoes of large ships can be done only at excessive cost and considerable delay. The wide transit shed with its railroad tracks and wagonways for drays and motor trucks has in many respects greater influence upon the expeditious interchange of freight between marine and land carriers than some types of freight-handling devices that cannot be properly adapted to the disposal of the various forms of freight in the general-cargo trade.

At the meeting of the Materials Handling Division of the A.S.M.E. in Philadelphia in December, 1921, a very interesting discussion brought out some of the advantages of two-story pier sheds.

Fig. 3 Pier No. 27, North Wharves, Philadelphia, Showing Bridge for Second-Deck Tracks

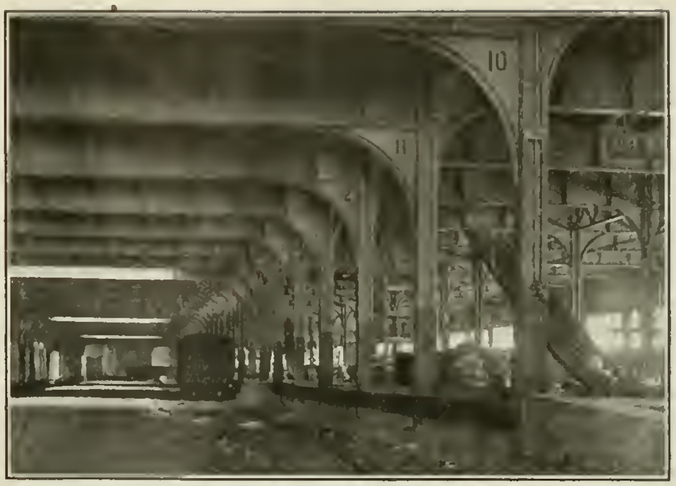

Fig. 4 Center Car Tracks and Depressed Wagonway on Municipal Pier No. 78, South Wharves, Philadelphia

Col. Fred Jaspersen explained the reasons leading up to the building and continued use of double-deck piers at Philadelphia as follows:

> When the first pier was built on these lines, the idea was that the lower floor would provide space for the collection of the ship's cargo, which arrived at the terminal at intervals; the merchandise was stored and classified on the lower floor. This left the second floor or upper deck, as it was termed, free to receive the ship's inbound cargo. Tracks on the upper deck of these piers make it as convenient to handle cargo from the upper deck as from the lower. The inbound cargo is classified and loaded into cars on the second floor and as soon as space is available in the ship, the stevedores start loading from the lower floor.
>
> We have found the cost. . . .to be lower in operating this type of pier, because the placing of cargo from the ship's hold to the upper deck was accomplished much quicker than it could have been done if the inbound cargo had been placed on the lower floor. It was found that *an average of three drafts could be placed on the second floor while two were being placed on the lower floor.* This scheme permitted better distribution of the men and employment of greater numbers without interfering with each other, which resulted in greater speed in the discharging and loading of cargo.

The bulkhead shed (which is usually a one-story head house flanking the inshore end of the pier) should prove to be an advantage with a more extensive use of tractors and trailers delivering freight to loading platforms of the shed along the street. It will keep many drays and motor trucks out of the pier altogether and tend to reduce congestion in the pier shed.

Large motor-truck elevators at the street end of the two-story pier shed that will enable local delivery to reach the upper deck direct from the marginal way to receive freight that has been discharged there, will greatly increase the usefulness of this type of structure. This will also avoid the necessity of many teams going on the first deck of the pier.

Railroad Tracks

The solution of securing the quickest dispatch of freight between railroad car and ship is to run the tracks directly on the pier. Depressed tracks (Fig. 4) in the center of the pier form a natural barrier to separate cargo space allotted to each steamship berth and in a sense divide the pier in half, which is a distinct advantage when the pier—or the double pier, as it might be called—is leased to two steamship lines. Two tracks are essential, one for each berth; but in the case of a pier long enough to accommodate two or more ships on each side, one additional running track along the center—or three in all—with crossover connections to the other two about midway in the length of the pier, is desirable to permit of car service to the outshore berths without interfering with cars assigned to, or interrupting the loading or unloading opposite, the inshore berths. Furthermore, the center location of tracks in an emergency, or when one side of the pier is not in use, will permit cars on all the tracks to be loaded or unloaded with freight from the steamship berths on either side of the pier by merely trucking through one line of cars after they have been properly spotted. Another advantage of center tracks is that they permit loading or unloading of cars under cover of the pier shed. In connection with these tracks, it is also desirable to provide a means of attach-

Fig. 5 Depressed Apron Track on Municipal Pier No. 78, South Wharves, Philadelphia

ing tackle equipment to the overhead structure to facilitate the loading or unloading of heavy parcels of freight from open or gondola cars. Many similar accessories of this character will add greatly to the economy of handling freight in the pier shed.

Apron tracks outside of the pier shed are always desirable, but where the pier width is limited it is questionable whether the covered cargo-deck area should be reduced to permit of their installation. The disadvantage of not having apron tracks for loading or unloading heavy commodities direct between car and ship may be far less serious than the congestion and confusion that would result from the restricted cargo-deck area in a narrow pier shed.

Some difference of opinion exists as to whether apron tracks should be depressed or laid flush with the pier deck. So far as the loading or unloading between ship and cars on the outside tracks is concerned, there is no particular advantage in either method. On the other hand, while the loading or unloading between ship and pier deck is underway, the tracks should be clear of cars, and this would lead to the belief that the tracks should be flush with the pier deck, in order to provide a deck-level place of deposit over the entire width of the apron for the drafts of cargo and also to facilitate trucking in and out of the shed. However, in the case of depressed tracks (Fig. 5), the sunken area outside the shed is not a very serious handicap if a platform space not less than 6 ft. in width and flush with the main pier deck is provided between the sunken pit and the pier shed for the handling of drafts of cargo. In any event, portable platforms laid across and spanning the width of the depression, in line with the loading operations, will provide the deck-level apron for its full width when required. The one great advantage of the depressed apron tracks is their use for bringing freight to the pier, or vice versa, when the berths are not occupied by the ships. When apron tracks are installed they not only can be, but invariably are, used to the greatest extent for transporting car shipments to and from the pier when the ship berths are unoccupied. In fact, their use for this purpose seems to greatly exceed that for loading direct between car and ship, and the importance of the car floors' being level with the main pier deck is obvious and offsets the slight disadvantage of a partially depressed apron for ship-loading operations, which may be readily overcome to a considerable extent, as discussed before.

For unloading or loading open cars on the apron tracks, the equipment installed on the pier for loading the ship would be available.

Vehicular Traffic

The other means of bringing goods to and from the pier, particularly the local deliveries, is by motor truck and teams. Ordinarily they cannot be confined to any particular location on the cargo deck, although the tendency is to follow a line of travel adjacent to the center car tracks, especially if the same entrance to the pier is used for both teams and cars. Congestion caused by drays and trucks could be reduced to a great extent by constructing bulkhead sheds, as discussed before.

Where the pier can be built wide enough, a depressed wagonway (Fig. 4) extending into the shed about three-fourths of the pier length will greatly facilitate team and truck delivery to and from the pier. It will not only keep many teams off the cargo deck but will permit loading or unloading of these units from a cargo deck built at wagon-floor height.

Another distinct advantage of the depressed wagonway, particularly with respect to a pier long enough to berth two or more ships, is that it affords a means of team traffic reaching the outshore berths without interfering with the working of freight on the cargo decks at the inshore berths. One car track laid along each side of such a wagonway will preserve the desirable feature of center car tracks—the space between tracks affording a thoroughfare for teams to reach the cargo decks at the outshore berth. When these tracks are not occupied by cars, either totally or partially, the teams can back up to the cargo-deck platform. With a layout of this character, however, it is essential that the pier be not only wide enough to accommodate the depressed wagonway—due to the fact that the space can be used for no other purpose—but, also, it must be wide enough to allow apron tracks to be installed, because the two tracks in the wagonway extending only three-quarters of the length of the pier will not permit of sufficient car service on a four-berth pier.

Loading and Discharging Ships

The importance of quick loading and unloading of ships, which in turn results in quick turn-around, cannot be overestimated, and any improvements in the existing methods that will at the same time satisfactorily meet the many complexities involved in handling freight at a general-cargo pier, will be a step in the right direction and one that will be welcomed.

As a rule, any discussion of loading or discharging general cargo centers around the efficiency of ship's gear in comparison with wharf

Fig. 6 Burtoning of Cargo to the Lower Deck of a Pier While Coaling Operations Are Under Way with Ship Breasted Off

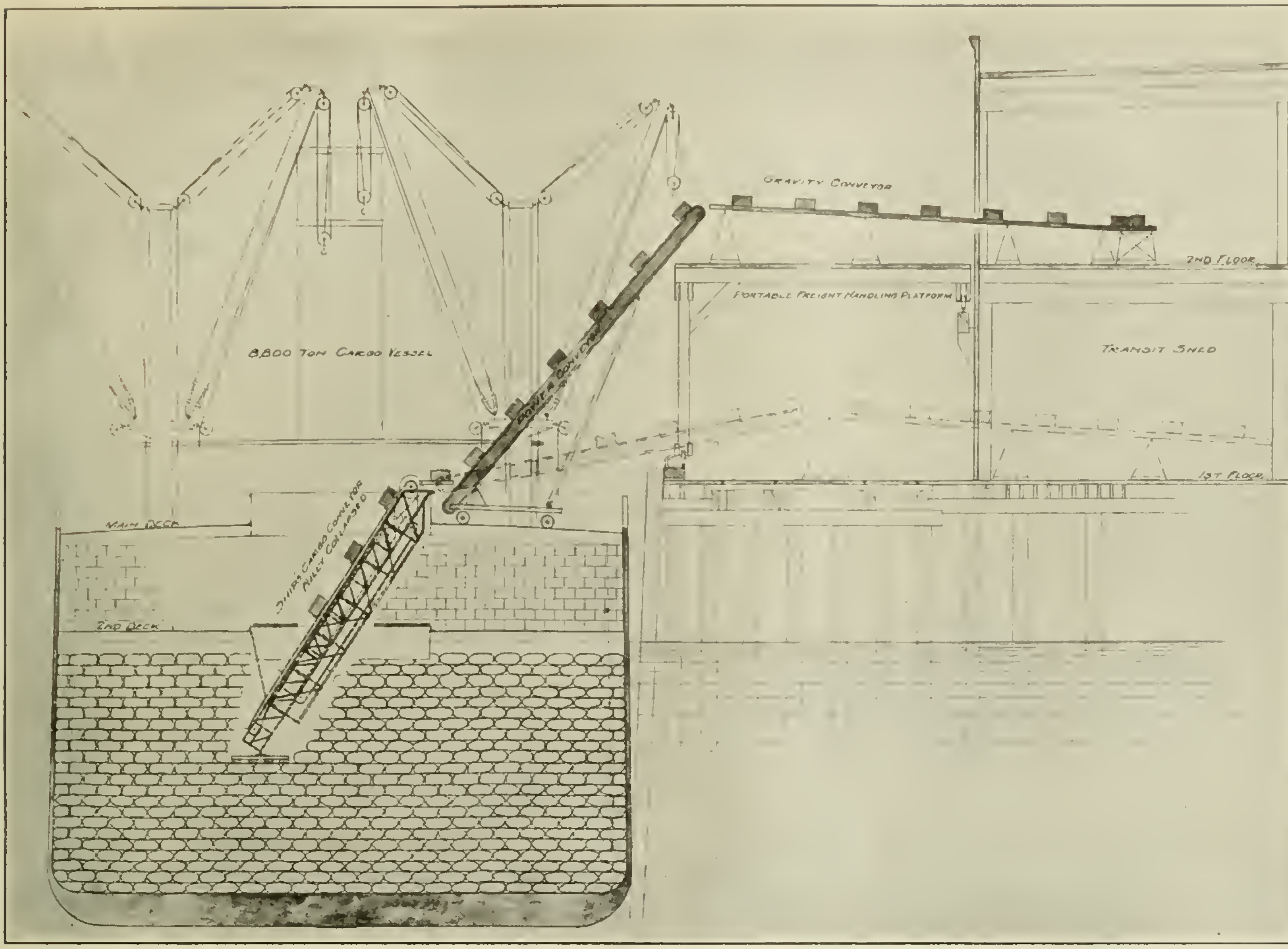

Fig. 7 Ship's Cargo Telescopic Conveyor, Port of Seattle, Wash.

cranes. It seems doubtful whether the wharf crane will displace the use of the ship's gear for handling general cargo until the operating and economic advantages of the crane have been demonstrated to be superior to the ship's winches by results of actual tests of each method conducted under working conditions.

Ship's gear forms one of the most flexible methods now in use that will meet all of the requirements for ship loading. It has one distinct advantage of being located on the ship and not on the pier, where space is valuable for other purposes. Its use is well understood and it can be worked over a narrow apron, thus permitting a maximum area of the wharf to be covered over.

Cargo masts on the pier will greatly increase the flexibility of loading with ship's gear in that it can operate by "Burtoning" over a wide apron or when the ship is breasted off (Fig. 6), and also over a greater length of the pier apron. The initial cost of cargo masts is small and there is practically no maintenance expense as there is nothing to get out of order.

In designing the side construction of a pier superstructure to permit of loading operations to be conducted at any point along the ship's berth, continuous door openings should be provided along the full length of the pier, and of a height sufficient to form no interference with the operation of the ship's gear. Generally, it is found that a clear opening of door height should be not less than 20 ft. for the first story. In the second story of the pier shed this height may be reduced, and door openings in alternate bays should provide sufficient access to the second deck for loading or unloading operations.

Remote-control, portable electric dock winches at some piers are desirable for furnishing power to supplement the ship's gear, although cases are known where pier operators have requested the port officials to remove publicly owned winches from the piers on account of the space they require.

Wharf cranes will generally accomplish all of the loading or unloading operations of the ship's gear, but their economy and speed still seem to be questioned. The pier must be built for their support and free operation, and unless the speed of ship loading and discharging is reduced, it is doubtful if they are able to control any more of the wharf area than the ship's gear. A wide apron is necessary, and besides skilful operation is required to avoid the ship's rigging. One drawback to providing wharf cranes on covered general-cargo piers is the high cost of installation and maintenance; another—in some cases—is the additional width of pier that is necessary for their operation.

In the case of a pier where apron tracks are built outside of the shed, it may be good policy to design the foundations and the superstructure for the future installation of semi-portal cranes, in the event of their use being warranted.

Other methods of loading ships, such as the portable conveyor systems, have proven successful at some of our West Coast ports for full cargoes of a uniform character such as bagged flour, but it is very doubtful if stevedores would set up such machines for loading parcel lots and then turn to the ship's gear or cranes for other freight that could not be handled on conveyors. The main objection to any equipment of this kind is the room it takes up on the pier when not in use, and also the necessity of changing to other kinds of equipment in loading miscellaneous cargo.

Freight Handling Within the Shed

The first essential for the economical movement of freight in the transit shed is a large area of unobstructed cargo-deck space. Stationary or semi-stationary equipment will generally prove to be obstructions in the way of flexibility of movement. Speaking on this subject, J. A. Jackson has said:

Industrial trucks and tractors with trailers provide to the fullest extent

that extreme flexibility so necessary and desirable for cargo handling on piers, the industrial truck being the more flexible of the two. If sufficient aisle space can be provided the tractor train is more desirable as it can handle a ton at lower cost than an industrial truck on account of the lower labor charge and due to the fact that the tractor—representing the major part of the investment—can be kept almost constantly at its legitimate work of hauling if sufficient trailers are provided.

The loading and unloading of trailers and trucks is still a job for manual labor and it must be admitted that in respect to this one problem the old hand truck has about everything beaten. It is for this reason that for very short movements the hand truck can make a better showing than either electric trucks or trailers.

Other methods such as overhead traveling cranes and telpher systems usually can operate only within certain restricted areas, particularly in two-deck structures where necessary columns form an obstruction, and the various movable units of either of these systems will invariably interfere with each other. Furthermore, the portable equipment before mentioned—in the event of its not proving satisfactory either generally or for particular purposes—does not represent an exorbitant initial cost and can be very readily removed from the pier if it proves to be unsatisfactory.

For interchange of freight between the first and second decks of a two-story pier shed, the large standard platform elevator and the automatic elevator and lowerator for handling packages of the size and weight for which it is particularly adapted, are the best means of communication; however, in the case of lowering goods from the second deck to the first, full advantage should be taken of the gravity type of equipment, such as chutes. In this connection it is believed that the straight chutes possess more advantages than the gravity spiral conveyors, in that the entire operation of lowering freight can constantly be seen by the operator stationed on the second deck.

Many other minor details in the design of piers, if given proper attention, will facilitate the general freight movement in the pier shed.

If the overhead girders and roof trusses are designed to allow for a moving load of, say, three tons at any point along the bottom chords, there need be no alarm over lifting occasional heavy loads from the pier deck level by means of tackle attached to these structural members; swivel tackle links built on them for such purposes—particularly over the railroad tracks—will prove very helpful in saving time in rigging tackle and at the same time result in such attachments being made to the structure at points where provision has been made in the design for it.

This particular allowance for loading in the design of the pier would also provide for future installations of overhead mechanical equipment that might prove serviceable in specific cases.

Tackle links built along the stringpiece of the apron will permit of easy tackle attachment to the pier for ship-loading operations with dock winches and will also go a long way to prevent lashing to columns, which invariably results in bent and battered door guides.

Links built in the side walls of depressed car pits have proved to be valuable for moving railroad cars with dock winches or other power equipment.

Dr. MacElwee, in a very commendable discussion on The Relation of Wharves and Warehouses in the Economical Handling of Materials, compares the advantages and disadvantages of terminal freight movement in "the pier and warehouse system" with "the quay and warehouse system," and offers the huge pier, or "quay pier," with its transit shed, warehouses, teamway, and railroad tracks as a solution of our water-front terminal problem with respect to the handling of "general" cargo, its chief advantages being the decrease in congestion and the shorter trucking movement.

The adoption of the wide transit shed, with its large, unobstructed cargo-deck area—whether the terminal is of the pier, double-pier, quay or quay-pier type—is obviously the fundamental essential for a successful and economical terminal facility for handling general cargo, and also the feature that will sooner or later permit of more extensive freight handling with mechanical equipment.

The success of any mechanical means of improving our freight-handling problem will be dependent upon the whole-hearted co-operation of all those who have any connection with terminal operation: the mechanical and electrical engineer must play just as important a part as the stevedore, the railroad or steamship operator, the port authority, or the terminal engineer.

Discussion

G. F. Nicholson[1] wrote that on the Pacific Coast freight was handled direct to and from vessels, and while gantry cranes, shearleg derricks, and locomotive cranes were used to handle large-tonnage export commodities such as lumber, iron and steel, both in the raw and manufactured state, when it came to handling imports consisting of boxed, baled, and sacked goods, light portable equipment such as tractors and conveyors were employed.

Ports like that of New York, where a large barge and lighterage business was carried on, should be well equipped with cranes, the straight-line roof type being the best for such work.

In addition to its heavy handling equipment the port of Seattle had a varied assortment of light portable equipment consisting of electric and gasoline tractors and trailers, incline conveyors, stacking elevators, etc. With a view to improving their service the port authorities were now constructing a ship-cargo telescopic conveyor which they had designed themselves, and it was expected that this machine would handle boxed, baled, and sacked goods weighing up to 500 lb. per package twice as rapidly as the equipment now used for that purpose. This conveyor, shown in Fig. 7, it was believed, would do away with the use of slings and the damage often resulting therefrom; permit of much better sorting of cargo to the hold of the vessel, as it could be handled by gravity conveyors to the main conveyor equipment; increase the speed of handling, as a continuous line of freight would be transferred from the hold of the vessel to the pile on this conveyor equipment; and reduce the cost of handling freight, as it would be carried to its destination on the wharf by the conveyor without rehandling.

J. A. Shepard,[2] who opened the oral discussion, called attention to the fact that one of the greatest difficulties in connection with materials handling today was the lack of adequate cost data. His mature opinion regarding the application of machinery to the handling of miscellaneous cargoes was that it could be made sufficiently flexible and could be installed in moderate but sufficient variety to meet all of the reasonable requirements of miscellaneous cargo handling. Too little had been said about cargo-handling machinery in the pier shed, which Mr. Shepard believed was destined to exercise perhaps a greater influence on the total economy than the use of machinery outside the shed. The traveling crane, able not only to hoist its load but to travel in all directions and cover absolutely a large area, he predicted, would in course of time be the solution of the handling problem within the pier shed.

H. E. Birch,[3] referring to the unloading of incoming freight to the upper deck of a double-deck pier, asked whether the cost of rehandling that freight on to the cars on the lower deck was taken into account; also what influence the type of stevedore labor available in any particular port had on the selection of the types of machinery or pier design.

Augustus Smith[4] said that the box car was a tremendous obstacle to any practical crane system, and a great step forward had been taken by the New York Central recently with its container car. The railroad rate system was based on the weight and value of freight and was unscientific. If it were only possible to have it based on the cost of handling, it would be easy to induce, through the Inter-State Commerce Commission, the roads to recognise convenient sizes of packages; and if manufacturers and shippers could be prevailed upon to use standard containers by a freight differential in their favor, a long step forward would be taken in facilitating the handling of such freight.

H. V. Coes,[5] chairman of the Materials Handling Division, who presided over the session, said that in his opinion, it ought to be possible, with the use of high-grade steel, to build a freight car from which the roof could be lifted; this would permit the use of containers of larger size and the tiering of freight, and immediately open up the use of cranes or other material-handling devices. It would also make loading a great deal easier than it was at the present

(*Continued on page 569*)

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[4] Pres., Bergen Point Iron Wks., Bayonne, N. J. Mem. A.S.M.E.

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The Determination of Chimney Sizes

By ALFRED COTTON,[1] ST. LOUIS, MO.

In this paper the author presents a simple and orderly system, based on accepted characteristics, for determining the sizes of chimneys. He has found that certain essential relations exist between capacity, draft, diameter, and height when connected in the manner described in the text.

Under any specific conditions there is a definite static draft for a given height and a definite "maximum capacity" for any given diameter. These are connected by a fundamental curve which is applicable to all chimneys under all conditions.

Charts are provided which give the static draft and maximum capacity of chimneys up to 500 ft. high and 25 ft. diameter, from which the working draft and capacity are found by means of the fundamental curve. Other charts give factors for various atmospheric temperatures, for altitudes; and for approximate work based on boiler horsepower. A problem is worked out to facilitate an understanding of the system.

IT IS PROBABLE that no engineering subject is in such a chaotic state as that of chimneys. While much excellent work has been done and many formulas, tables and charts have been prepared, chimneys are nevertheless usually designed by rule of thumb, and there are plenty of cases where their performance is either much greater or much less than was expected.

It is believed that the method of proportioning chimneys outlined in what follows has the merit of giving definite sizes which are entirely free from conjecture, in a very simple and consistent manner.

Description of the Method

It is convenient to consider the available draft at the chimney

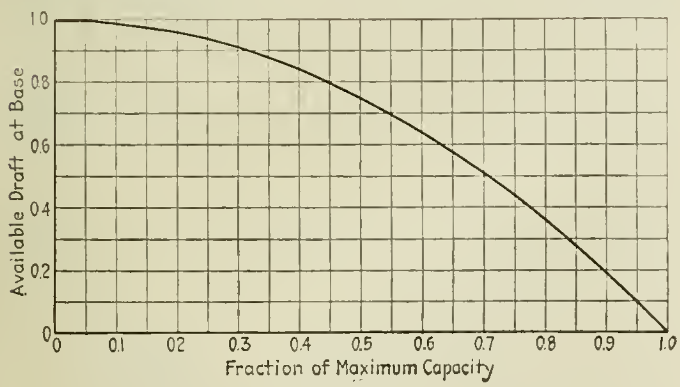

FIG. 1 RELATION OF DRAFT FRACTION TO CAPACITY FRACTION (AVAILABLE DRAFT RATIO)

base as being the static draft less the draft lost by chimney friction and by acceleration of the gases, and this must equal or exceed the draft necessary to operate the boiler, etc.

The static draft is the vacuum prevailing under an imaginary condition when no gases are flowing. It is an absolutely definite quantity for any given circumstances and forms the starting point of this method.

The chimney friction varies as the square of the velocity of the gases. If the velocity is progressively increased, a point is reached where the chimney friction is equal to the static draft. This is the "maximum capacity," and it is just as absolute and definite a quantity for any given circumstances as is the static draft from which it is determined, and it forms the end point of the method.

The draft loss due to chimney friction is in direct proportion to the height of the chimney. So also is the static draft. If we double the height of the chimney, we double both the static draft and the draft loss, and the maximum capacity is unaltered.

Since the chimney friction increases as the square of the velocity of the gases, the resulting curve is a parabola in all cases. This curve is presented in Fig. 1, and relates the load expressed as a fraction of the maximum capacity to the available draft expressed as a fraction of the static draft. This is a fundamental curve which applies to all chimneys at all temperatures of gases and of the atmosphere and at all altitudes.

Static Draft

Figs. 2 and 3 give the static draft for chimneys 100 to 500 ft. high at sea level dealing with gases up to 1200 deg. fahr. in temperature when the atmosphere is at 60 deg. Another chart in the complete paper deals similarly with chimneys from 0 to 100 ft. in height. Fig. 4 gives factors with which to multiply the static draft found

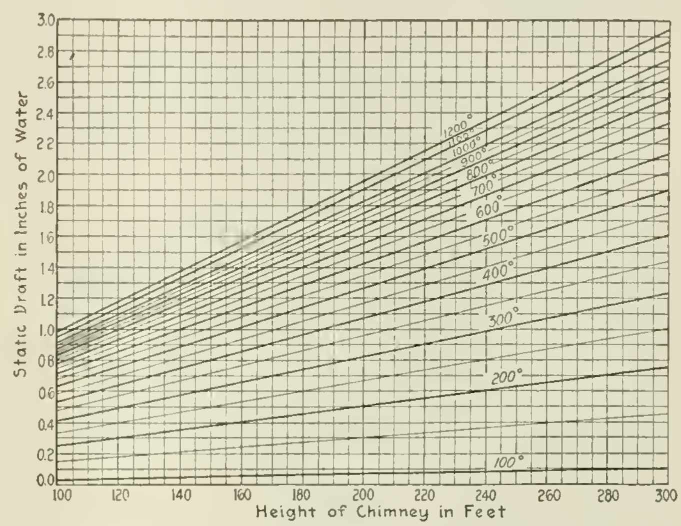

FIG. 2 STATIC DRAFT OF CHIMNEYS FROM 100 TO 300 FT. HIGH WITH GAS TEMPERATURES FROM 100 TO 1200 DEG. FAHR. AT SEA LEVEL WITH ATMOSPHERE AT 60 DEG. FAHR.

(Curves marked with mean temperature of gases in chimney in deg. fahr.)

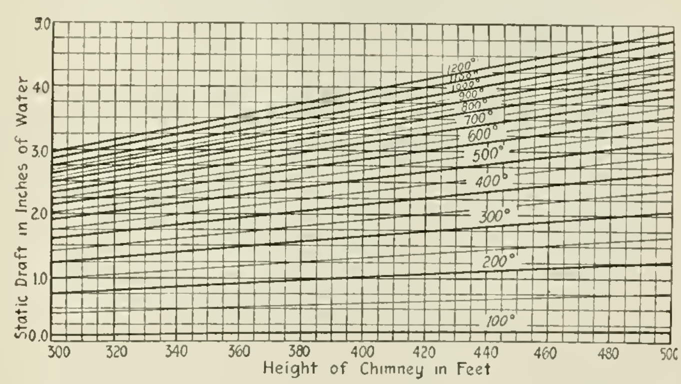

FIG. 3 STATIC DRAFT OF CHIMNEYS FROM 300 TO 500 FT. HIGH WITH GAS TEMPERATURES FROM 100 TO 1200 DEG. FAHR. AT SEA LEVEL WITH ATMOSPHERE AT 60 DEG. FAHR.

(Curves marked with mean temperature of gases in chimney in deg. fahr.)

from Figs. 2 and 3 to obtain the static draft for atmospheric temperatures other than 60 deg.

Temperature of Gases in Chimney

The author's article on Loss of Heat in Brick Chimneys, published in *Power Plant Engineering*, Aug. 1, 1921, and which forms an appendix to the complete paper, includes some curves of temperature drop. These lead to the factors of Fig. 5, by which the mean temperature in the chimney may be found.

Altitude and Static Draft

The static draft at any barometric pressure B in inches of mercury is that at sea level multiplied by $B/30$. If the same load is to be carried at altitude as would be carried at sea level, then the same weight of gases must be dealt with. Since the density of

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Contributed by the Fuels Division and presented at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS. Abridged. All papers are subject to revision.

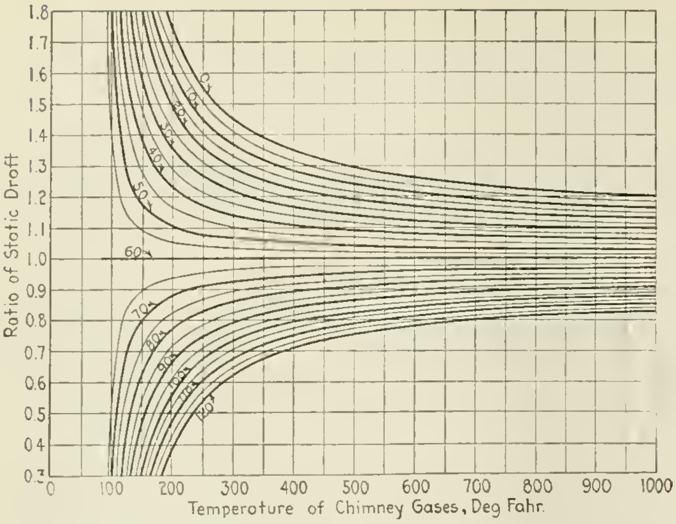


Fig. 4 Relation of Static Draft of Chimneys with Temperatures of Atmosphere from 0 to 120 Deg. Fahr. to That at 60 Deg. Fahr.
(Curves marked with temperature of atmosphere in deg. fahr.)

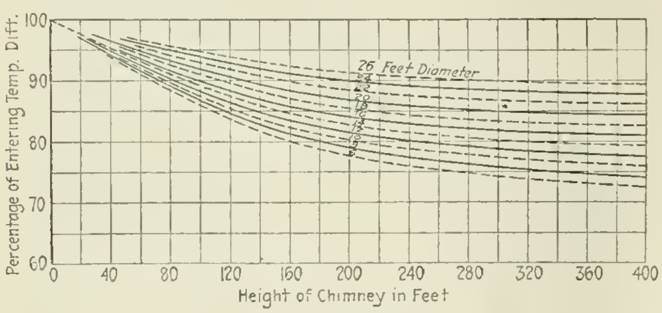


Fig. 5 Factors for Finding the Mean Temperature of the Gases in Chimneys

Procedure (Masonry Chimneys):

A = observed temperature of atmosphere
E = observed temperature of gases entering chimney
P = percentage appropriate to diameter and height as read from chart
G = temperature of gases entering chimney above that of atmosphere $= E - A$
C = average temperature of gases in chimney above that of atmosphere $= G \times P$
$C + A$ = average temperature of gases in chimney.

the gases is less, their velocity must be higher, and the height of chimney necessary at altitude to provide sufficient draft to do the same work as at sea level, will be the sea-level height divided by $(B/30)^2$, or multiplied by its reciprocal which is given in Fig. 6.

Maximum Capacity

Menzin, in his paper on Proportioning Chimneys on a Gas Basis, Trans. A.S.M.E., 1916, went so carefully over all the available data on chimney friction that the formula he presented has been used. Fig. 7 gives the maximum capacities of chimneys from 5

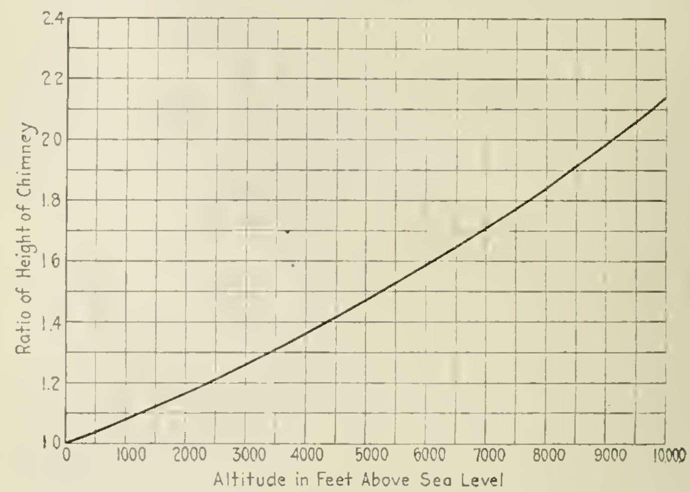


Fig. 6 Effect of Altitude on Height of Chimneys

to 25 ft. in diameter for various mean temperatures of gases with the atmosphere at 60 deg. at sea level. Other charts in the complete paper cover the range for diameters of from 0 to 10 ft. The maximum capacities as read from Fig. 7 are to be multiplied by the appropriate factor read from Fig. 8 when the atmospheric temperature is other than 60 deg. fahr.

It is convenient to assume that the velocity of the gases remains constant. Then the maximum capacity at altitude is that at sea level multiplied by $B/30$.

Acceleration of Gases

The pressure difference required to accelerate the gases is conven-

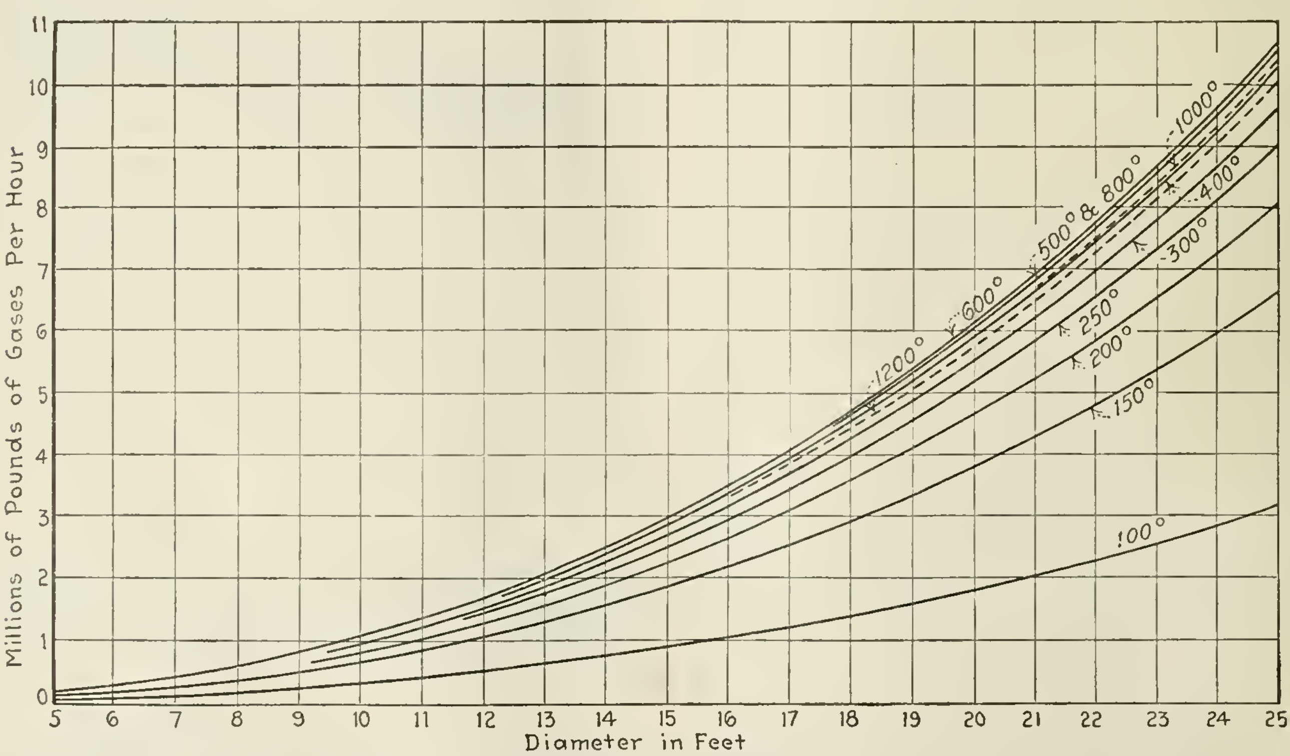


Fig. 7 Maximum Capacity of Chimneys from 5 to 25 Ft. in Diameter at Different Gas Temperatures from 100 to 1200 Deg. Fahr. at Sea Level with Atmosphere at 60 Deg. Fahr.

iently stated as draft loss, and curves showing this draft loss at maximum capacity for each diameter have been drawn in Fig 9, for different temperatures. Other charts in the complete paper covers the range for diameters of from 0 to 10 ft. The fraction of the draft loss for any desired fraction of the maximum capacity is the same for all maximum capacities. Fig. 10 gives this fraction.

The draft loss at sea level multiplied by $B/30$ gives the draft loss for altitudes.

Available Draft

Enter Fig. 1, with the ratio of available draft to static draft, and read the fraction of maximum capacity. Divide the required weight of gases by this fraction and use the resulting maximum capacity to find the requisite diameter. Or with given diameter, read the maximum capacity and state the required capacity as a fraction of it. Divide the required draft by the fraction read from

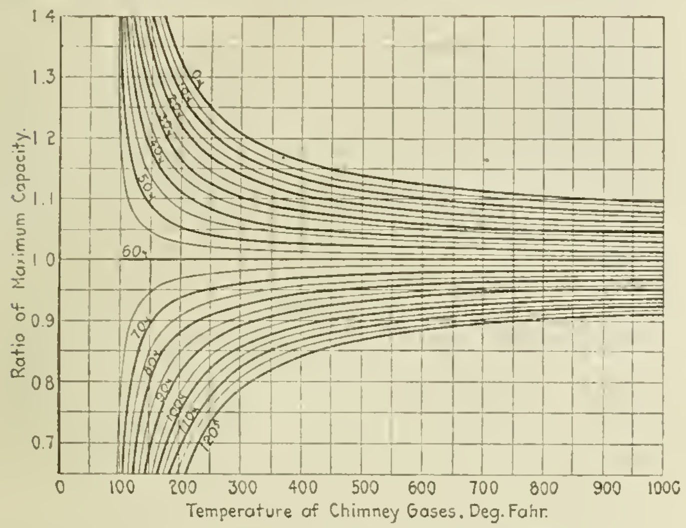


Fig. 8 Relation of Maximum Capacity of Chimneys with Temperatures of Atmosphere from 0 to 120 Deg. Fahr. to That at 60 Deg. Fahr.

(Curves marked with temperature of atmosphere in deg. fahr.)

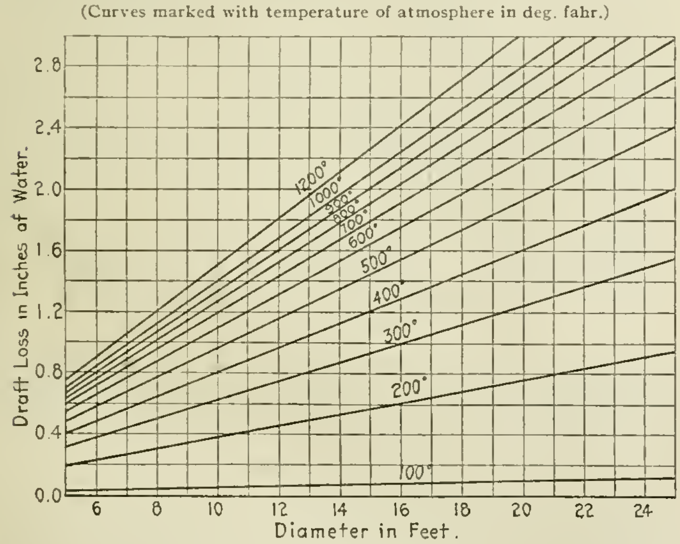


Fig. 9 Draft Loss Due to Acceleration of Gases at Maximum Capacity of Chimneys from 5 to 25 Ft. in Diameter with Temperatures of Gases from 100 to 1200 Deg. Fahr. at Sea Level

(Curves marked with mean temperature of gases in chimney in deg. fahr.)

Fig. 1 and get the equivalent static draft. Add the draft required to accelerate the gases and read the height of chimney from Fig. 2 or Fig. 3. Several combinations of height and diameter can be found for any circumstances very quickly.

Draft Required

The draft required at the base of the chimney is made up as follows:

1 *Vacuum Over Fuel Bed.* Fig. 11 shows the vacuum required in the furnace chamber for burning various fuels. The values are fair averages which accord with the author's experience with reasonably clean fires when hand firing and with average conditions of stoker operation. The broken-line curves were kindly supplied by Mr. Thomas A. Marsh, Mem. A.S.M.E. With forced draft, a vacuum over the fire of about 0.1 in. should be maintained.

2 *Draft Loss Through Boiler Setting.* A curve should usually

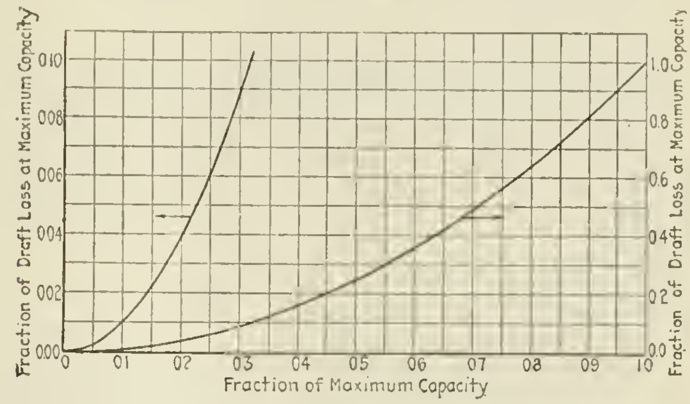


Fig. 10 Relation of Draft-Loss Fraction Due to Acceleration of Gases to Capacity Fraction

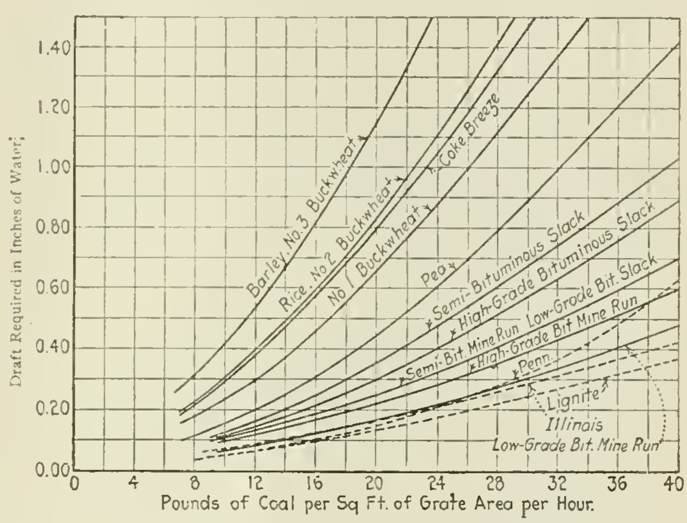


Fig. 11 Draft Loss through Fuel Bed with Different Fuels

(Note—Broken-line curves are for coal burned on chain-grate stokers and as drawn by Green Engineering Co.)

be obtained from the boiler manufacturer based on some proportion of excess air with the fuel to be used.

The draft loss through a horizontal, diagonally baffled, 14-high water-tube boiler burning bituminous coal with 13 per cent of CO_2 in the flue gases is given in Fig. 12.

The effect of an alteration in the amount of excess air as indicated by the proportion of CO_2 in the flue gases is shown approximately by the curves drawn in Fig. 13. Precise factors are not possible, but these are sufficiently accurate for the present purpose. The draft loss for any percentage of CO_2 is to be multiplied by the appropriate factor to find the draft loss at some other percentage of CO_2.

3 *Draft Loss Through Damper.* Some may prefer to allow a little draft loss through the damper, the damper being not fully open, as a factor of safety. But this is quite unnecessary with the method of treatment being described. Of course, in some ill-designed plants there may be a real draft loss through the damper frame owing to its being too small, or through the damper's causing serious distortion of the stream lines when fully open.

4 *Draft Loss Through Flues.* The draft loss through flues is commonly taken as 0.1 in. of water for each 100 ft. of length and 0.05 in. for each right-angle turn. This value results in the curves of gas weights and velocities of Figs. 14 and 15 for a temperature of 540 deg. and for rectangular flues whose sides have a ratio of 2 : 1. Other figures in the complete paper give factors for finding the weight and velocity at other temperatures for the same draft loss, and the effect of the shape of the cross-section of the flue. A

further development results in the curves of Fig. 16 which are based on the gas weights of Table 1.

TABLE 1 WEIGHT OF FLUE GASES PER BOILER HORSEPOWER

Conditions	Pounds of gases per hp.
Coal, natural draft	90
Coal, forced fraft	60
Natural gas	60
Oil	45
Blast-furnace gas	100

The loss due to elbows is generally assumed as 0.05 in. for right-angle turns whose inside radius is not less than the width of the flue. The effect of different amounts of excess air on the draft loss in flues is the same as for the boiler setting as shown by Fig. 13.

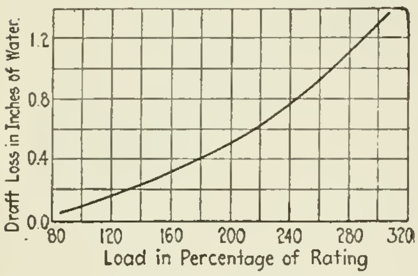


Fig. 12 Draft Loss through Diagonally Baffled Boiler 14 Tubes High with Superheater, Burning Bituminous Coal with 13 per cent of CO_2 in Flue Gases, at Sea Level

Weight of Gases

The weight of gases to be dealt with from any given fuel depends upon the proportion of excess air. It is convenient to calculate the weight of gases with different proportions of excess air per pound of "combustible." Any percentage of refuse, including unburned coal going to the ashpit, can then be used to find the weight of gases per pound of dry coal or of coal "as fired." The efficiency of the boiler and furnace will determine the weight of coal per horsepower or per unit weight of steam, and the weight of coal to be burned can then be found.

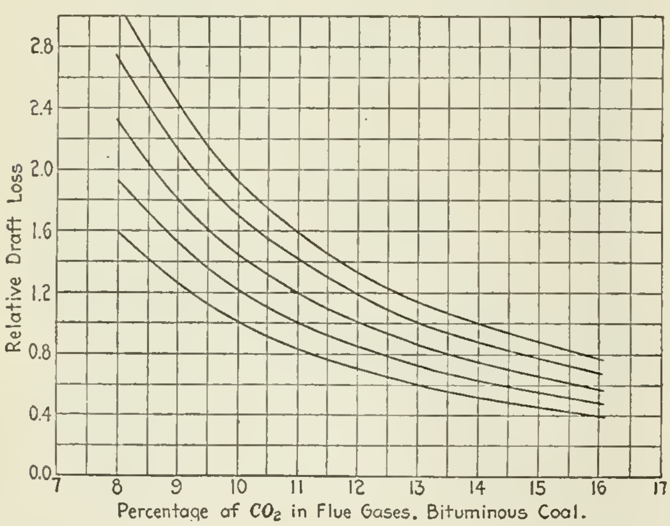


Fig. 13 Relative Draft Loss through Boilers Burning Bituminous Coal with Varying Proportions of Excess Air as Indicated by the Percentage of CO_2 in the Flue Gases

Induced Draft

Chimneys for induced draft are computed in exactly the same manner as in other cases. Since it often happens that loads are increased later owing to the ease of doing so with induced draft, it is advisable to allow at least 0.2 in. of available draft at the fan discharge.

Approximate Sizes

Fig. 17 is drawn for a working capacity of 30 per cent of the maximum capacity. The natural-draft curve is computed at 90 lb. of gases per boiler hp., the forced-draft curve at 60 lb., and the oil-burning curve at 45 lb.

Fig. 10 shows that at 0.3 of maximum capacity the draft loss due to acceleration of gases is 0.09 of that at maximum capacity, or, say, 0.10 for use in this approximate way. Fig. 1 shows that the available draft at 0.3 of maximum capacity is 0.91 of the static draft. Therefore the draft required at the chimney base divided by 0.9, for this approximate work, and added to the draft loss due to acceleration of gases gives the required static draft. The necessary height of chimney can then be directly read from Fig. 2 or Fig. 3 after making due allowance for temperature drop with the aid of Fig. 5.

The accuracy of the results depends only upon that of the constants. For all ordinary cases only a few of the charts are used, and it is an exceedingly simple matter to solve any problem.

Chimney Study

A central power station is to have groups of four 1400-hp. boilers to each chimney. The boilers are to be 14 tubes high and are to carry peak loads of 300 per cent of rating when the exit gases will be at 640 deg. Forced-draft stokers are to burn bituminous coal of known analysis with 30 per cent of excess air.

An approximate idea of the chimney is first arrived at. The total horsepower to be handled is 16,800, for which a diameter of 16 ft. is read from Fig. 17.

The draft required at the base of the chimney is found to be 1.55 in., made up of 1.3 in. draft loss through boiler (from Fig. 12), 0.15 in. draft loss through the flues, and 0.1 in. vacuum over the fire. Dividing this by 0.9 gives 1.72 in. as equivalent static draft, to which is added an assumed 0.1 in. for acceleration of gases, making a total static draft of 1.82 in. Assuming a mean temperature of chimney gases of 550 deg., a height of 270 ft. is found from Fig. 2.

The combustion data for the coal are worked out and the total weight of gases per pound of combustible found. Using the predicted boiler and furnace efficiency, the weight of combustible per hour is found and then the weight of gases per hour. Tabulation of data is then commenced as in Table 2, using a number of diameters above and below the first approximation. The first approximation of heights appropriate to the listed diameters is given in column 7 and is made on the assumed mean temperature and gas acceleration loss. A close determination is now made of mean temperature in accordance with each combination of approximate height and diameter and of the actual loss due to acceleration of gases. This leads to a new series of heights as entered in column 15. A curve of heights as in column 15 is now drawn against the diameters of column 1 as the full line of Fig. 18 and simplifies the final choice. Such a curve shows the practical limits at each end of the series very decidedly.

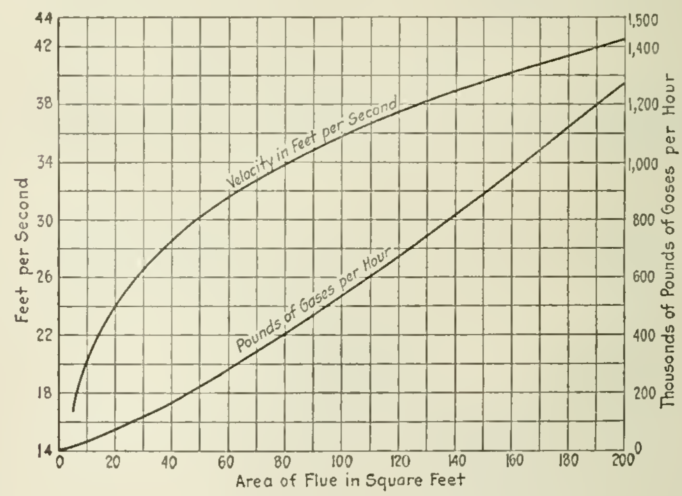


Fig. 14 Working Capacity of Rectangular Flues from 0 to 200 Sq. Ft. in Cross-Sectional Area with Sides in Ratio of 2 : 1 with Gases at 540 Deg. Fahr. at Sea Level, Giving a Draft Loss of 0.1 In. of Water per 100 Ft. of Length

It was pointed out by Deinlein that of a series of possible chimneys, the one whose product of diameter by height was the smallest would be the least expensive. These products are entered in column 19 of Table 2 and their curve drawn in Fig. 18 as the broken line. The lowest point in this curve occurs at 14 ft. 6 in. diameter where the height is 289 ft. The author is indebted to Mr. George H. Gibson, Mem. A.S.M.E., for this information.

A problem frequently met with is that of modernizing and

increasing the steaming capacity of a plant while using the existing chimney.

A curve of exit gas temperatures is first drawn and then a curve of the corresponding mean temperatures of the chimney gases as in Fig. 19. These are used to determine the characteristics of the chimney as in Fig. 20; and as this is based on weight of gases, it must be related to Fig. 19, which necessitates a curve of gas weight per horsepower depending on the curve of efficiency. The draft loss through the boilers is determined and plotted. The areas and arrangement of flues are carefully examined because desirable reduction of their draft loss can usually be made by redesigning them. The predicted flue draft loss added to the boiler draft loss and to the vacuum necessary over the fire, will enable the curve of draft required at base of chimney to be drawn as in Fig. 19. With the mean temperature of chimney gases, the static draft for different loadings is read from Fig. 2 and plotted.

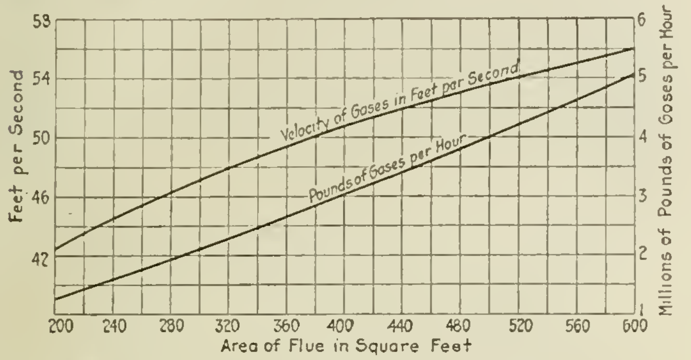


Fig. 15 Working Capacity of Rectangular Flues from 200 to 600 Sq. Ft. in Cross-Sectional Area, with Sides in Ratio of 2 : 1 with Gases at 540 Deg. Fahr. at Sea Level, Giving a Draft Loss of 0.1 In. of Water per 100 Ft of Length

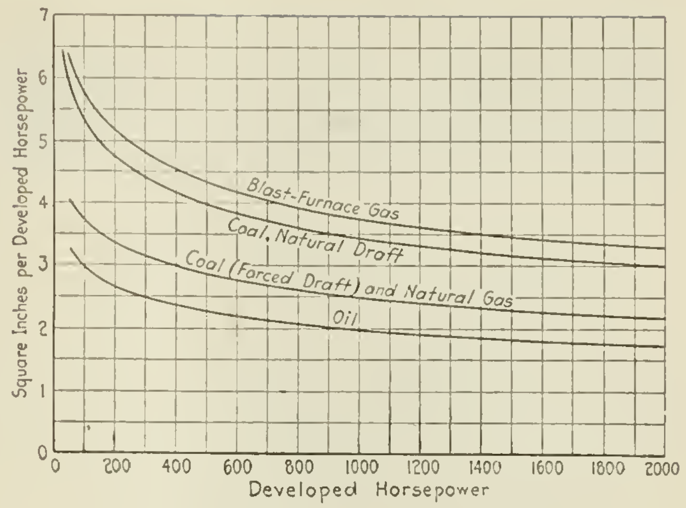


Fig. 16 Area of Rectangular Flues in Sq. In. per Developed Horsepower with Sides in Ratio of 2 : 1 Which Will Give a Draft Loss of 0.1 In. of Water per 100 Ft. of Length at Sea Level

The fraction of static draft for different fractions of maximum capacity is found from Fig. 1, and the equivalent draft for each percentage of boiler rating noted. The loss due to acceleration of gases is then found and deducted therefrom, leaving the available draft at the base of the stack at each percentage of rating at which the boilers might be worked. Curves are then drawn of these available drafts as in Fig. 20. The draft required at different ratings is read from Fig. 19 and enables the broken-line curve of maximum chimney load at different boiler-rating loads to be drawn in Fig. 20.

The actual boiler hp. which the chimney will carry at different boiler ratings is obtained by dividing the total gas weights of

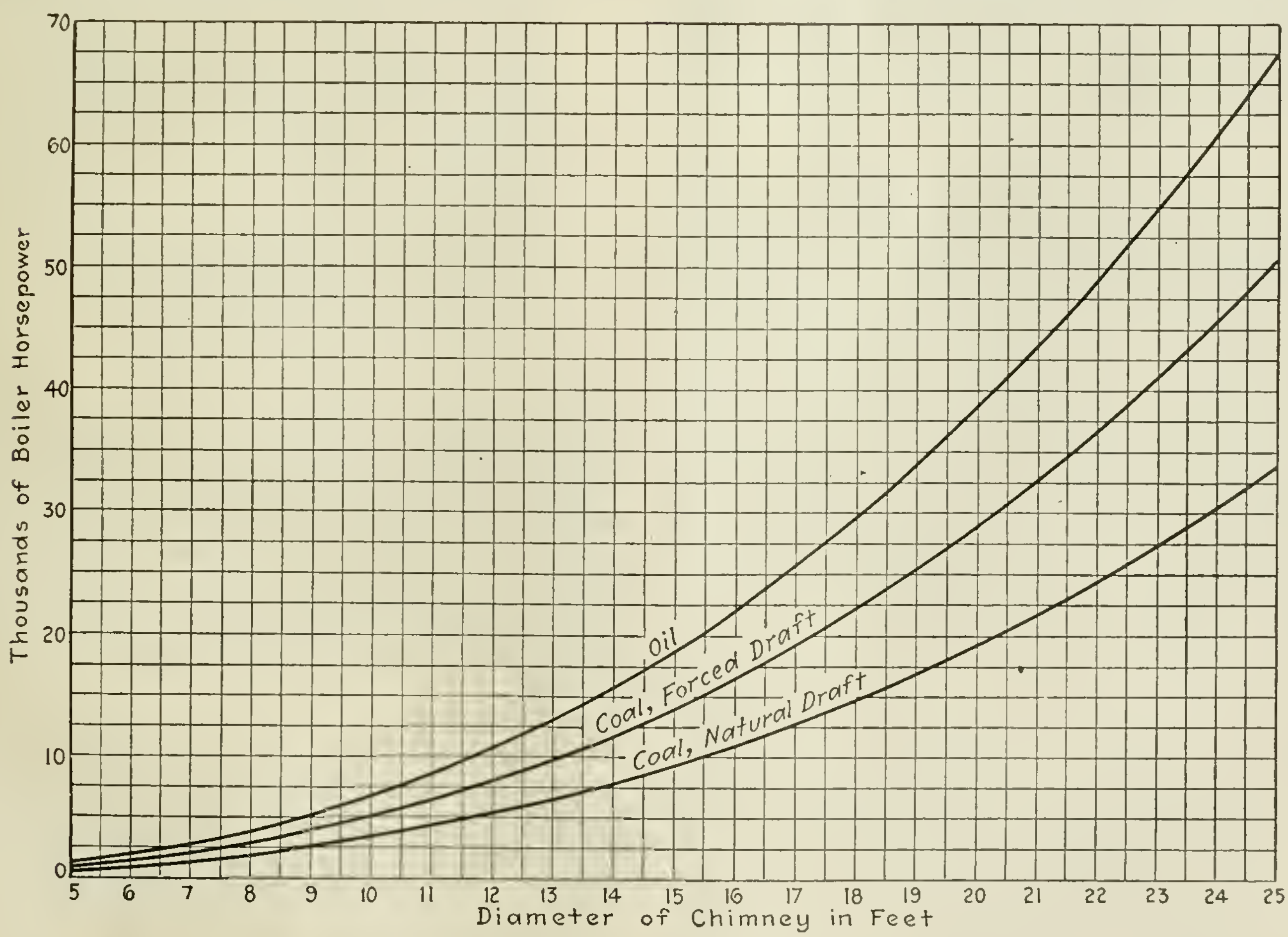


Fig. 17 Working Capacity of Chimneys from 5 to 25 Ft. in Diameter, Based on Boiler Hp. with Atmosphere at 60 Deg. Fahr. at Sea Level

(Maximum capacity = 95 per cent of maximum capacity with mean temperature of gases at 900 deg. fahr. Working capacity = 30 per cent of maximum capacity (or 28.5 per cent of maximum capacity at 600 deg. fahr.). Weight of gases = 90 lb. per hr. for natural-draft coal, 60 lb. per hr. for forced-draft coal, and 45 lb. per hr. for oil, per boiler hp.)

Fig. 20 by the gas weight per hp. of the curve of Fig. 19. To show this more clearly, the curve of Fig. 21 may be drawn. This curve emphasizes how the chimney capacity is governed by the draft loss of the boilers and flues. If the flues were enlarged, the chimney capacity would be greatly increased. This curve also shows that the capacity of the chimney is increased enormously if the boilers are run at low ratings owing to the much lower draft loss at low loads.

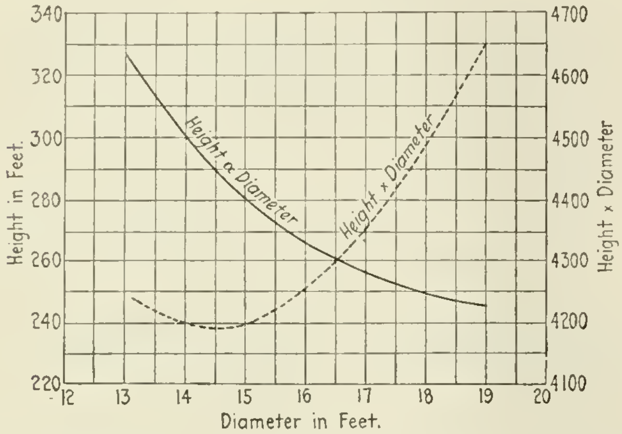


Fig. 18 Chimney Study Giving a Series of Combinations of Height and Diameter

The requirements may be met by reducing the excess air, by improved methods of firing, by installing induced draft, or by adding more boilers and running at lower boiler ratings. The first and last methods increase boiler efficiency and save coal, while the second method increases the coal consumption by running at higher boiler ratings where the efficiency is lower.

Other examples are given in the complete paper which show that the system is as well adapted for finding approximate but reliable chimney sizes as it is for making more accurate studies of chimney characteristics for large and important plants such as the one immediately preceding.

Discussion

The discussion was opened by the reading of a communication from Julian C. Smallwood[1] in which he pointed out that the author's method was an elaborate structure based on two slender supports, namely, Menzin's coefficient for frictional resistance in chimneys, and the author's estimate of mean temperatures of chimney gases.

Menzin had assumed the hydraulic equation for friction to hold, although there was no experimental proof that for such large gas flows as those in present-day chimneys that it did hold; and had selected the coefficient 0.008 as a compromise between 0.012, from the crude experiments of Gale, and 0.006, from the limited data of Peclét, both obtained prior to 1890 and therefore scarcely up to date.

The author's calculations for chimney height were based on mean stack temperatures instead of temperatures at the base of the stack, which was a correct procedure. Curves were presented in the paper to show the relation between mean temperature of stack gases and temperature at base. These curves were based on experiments made at the Massachusetts Institute of Technology and still more recent ones at Johns Hopkins University. Professor Smallwood could not speak for the former, but having himself conducted the latter experiments, he wished to emphasize the fact that the temperature gradients obtained had been influenced not only by air infiltration through idle boilers but by leakage at the joining of the breeching and the chimney. This possibly accounted for the rapid temperature drop of the gases upon leaving the breeching, as shown by Figs. 2, 3, and 4. As had been pointed out in the report of the Johns Hopkins tests, it was absolutely essential for correct chimney design that the mean stack-gas temperature be calculated with some degree of precision, and that loading of the chimney by cold air be prevented. If the author had given the Johns Hopkins tests much weight, his results would possibly be more applicable to chimneys leaking air at the base than to the tightly sealed chimneys of modern large power plants.

Professor Smallwood questioned the author's statement that the maximum capacity of a chimney was independent of its height. This might be true if the stack gases would only remain at a constant temperature; as a matter of fact they inevitably decreased, radiation

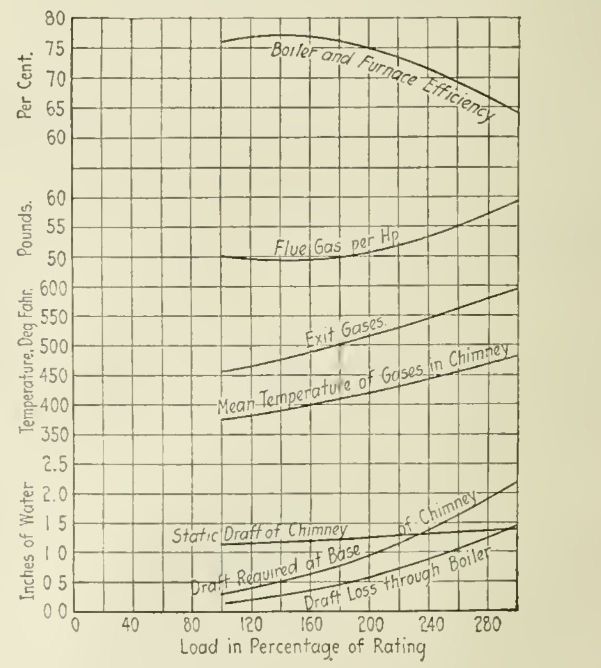


Fig. 19 Chimney Study. Performance Data of an Existing Chimney

alone being sufficient to account for this phenomenon. The higher the chimney, the lower became the temperature of the issuing gases. As the temperature fell, the density of the gases increased, and the increment of draft due to each increment of height became less and less. On the other hand, the frictional resistance per increment of height remained constant, and in consequence there was a limit beyond which the increased frictional resistance was greater than the increased draft, resulting in a lessening of available draft at the base, and in capacity.

[1] Assoc. Prof. Mech. Eng., Johns Hopkins Univ., Baltimore, Md. Mem. A.S.M.E.

TABLE 2 CHIMNEY STUDY

(1) Diameter in feet	(2) Maximum capacity as in Fig. 7	(3) Working capacity = fraction of maximum capacity	(4) Draft required, fraction of static draft	(5) Draft required, 1.55 in. ÷ col. (4)	(6) Static draft required = col. (5) + 0.1 for gas acceleration	(7) Height with mean temperature at 550 deg. fahr.	(8) Factor for mean temperature	(9) Mean temperature difference	(10) Mean temperature of chimney gases	(11) Draft loss by gas acceleration at maximum capacity	(12) Fraction of gas acceleration at working capacity	(13) Gas acceleration at working capacity	(14) Total static draft required	(15) Height required at mean temperatures of col. (10)	(16) Factor for mean temperature	(17) Mean temperature difference	(18) Mean temperature of chimney gases	(19) Product of neight by diameter
13	2,000,000	0.429	0.815	1.902	2.002	297	0.795	461	521	1.30	0.183	0.238	2.140	327	0.792	459	519	4251
14	2,380,000	0.360	0.870	1.782	1.882	280	0.805	467	527	1.40	0.130	0.182	1.964	300	0.803	466	526	4200
15	2,820,000	0.304	0.908	1.707	1.807	268	0.815	473	533	1.51	0.092	0.139	1.846	280	0.814	472	532	4200
16	3,320,000	0.258	0.932	1.663	1.763	261	0.824	478	538	1.62	0.066	0.107	1.770	266	0.824	478	538	4256
17	3,860,000	0.222	0.950	1.632	1.732	257	0.833	483	543	1.73	0.049	0.085	1.717	256	0.833	483	543	4352
18	4,450,000	0.193	0.962	1.611	1.711	253	0.841	488	548	1.84	0.037	0.068	1.679	249	0.842	488	548	4482
19	5,090,000	0.169	0.971	1.596	1.696	251	0.849	492	552	1.95	0.028	0.055	1.651	245	0.850	493	553	4655

Despite the preceding criticisms, Professor Smallwood considered that the author had made a real contribution toward the solution of the problem of chimney proportioning and that his method of arriving at definite results was by far the best yet presented. It was of the highest importance, however, that additional experimental data be obtained, and power-plant superintendents should coöperate in experimenting on large chimneys to determine friction losses, the factors with which they vary, and the laws relating them; determining the exact relation between temperature of gases and height of chimney; and investigating the influence of air infiltration, down drafts, stratification, eddy currents, etc. Until this was done, chimney design must remain much where it was.

T. A. Marsh[2] wrote that chimneys were not power generators and were not subject to classification on a horsepower basis. They fulfilled the same function as fans and should be rated by the same units of measurement, namely, gas volumes and pressures.

The large problem was one of judgment as to what variables to use. Such items as the flue-gas temperature as affected by operating conditions, friction losses as affected by fouling of boiler passes, quality of coal and provision for worst coal as affecting the weight of air, were all subject to considerable variation, and judgment based on ample experience was required to select the proper values. There was also the question of the probable operating conditions that might exist five or ten years hence in the plant in reference to plant development and growth, as well as that of the capital investment for plant expansion.

E. L. Hopping,[3] who opened the oral discussion, said that some

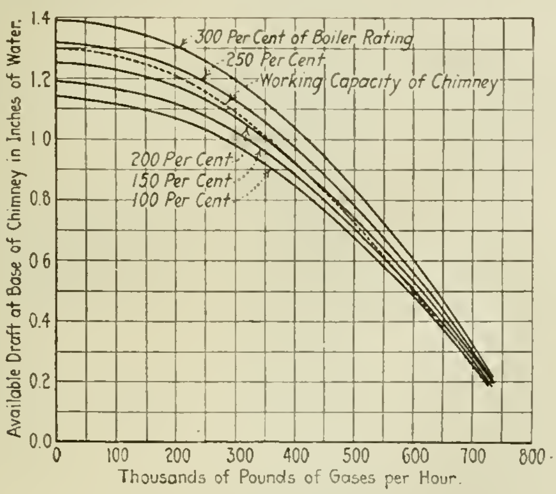


Fig. 20 Chimney Study. Working Load of an Existing Chimney at Different Boiler Ratings

years ago he had occasion to design the stacks for a modern plant, and found that the various formulas available for that purpose gave stack diameters ranging from 8 to 12 ft. for a given case. The old stack formulas, which were based on hand firing, would not apply to the great variety of conditions obtaining in stoker firing, and in this respect he felt that the author had presented something definite that could be depended upon.

Great care had to be exercised in making assumptions regarding gas conditions—whether they would be uniform throughout the stack or whether considerable excess air would filter in at some intermediate point. Further, radiation losses would be greater in steel stacks than in those built of brick unless the former were lined from bottom to top.

N. E. Funk[4] said that while two of the fundamental quantities used in the author's method were assumptions based on scanty experimental data, he nevertheless believed that it would be found to yield more accurate results than anything else published on the subject. The formula for friction might be open to question as the friction varied with the condition of the surface, and the surfaces differed widely as regarded roughness. The velocity to be used in such calculations was that at the sides of the stack where the friction occurred, and not the average velocity of flow through the stack cross-section, which was higher.

A. G. Christie[5] confirmed what Mr. Hopping had said in regard to the diversity of results obtained from various stack formulas. The previous summer, in connection with the design of chimneys for the pulverized-fuel-burning station being constructed in St. Louis, he had had some of his assistants gather a large amount of

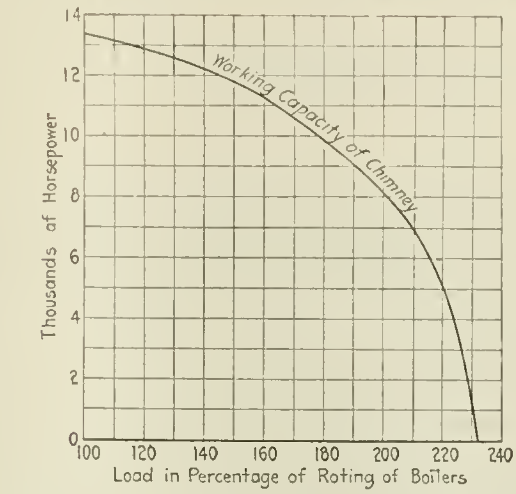


Fig. 21 Chimney Study. Reduction of Working Capacity of an Existing Chimney at Increased Boiler Ratings

performance data from chimneys in modern plants in order to determine whether an empirical formula might be derived that would be suitable for the work in hand, and it had been found that practically every chimney considered had been designed, with certain modifications, according to Kent's original formula.

Professor Christie agreed with Mr. Funk that surface friction was involved as well as fluid friction. In the work which Professor Smallwood had conducted at Johns Hopkins, thermocouples having been found untrustworthy, a large resistance thermometer had been built to measure the average temperature across the chimney. This fitted the inside of the stack nicely and could be lowered from top to bottom. For a long time no explanation had offered itself as to the very great temperature drop that took place between the outlet of the boiler and the top of the stack; but at last it was found that the breeching had been cemented into the stack cold, and that heating had dished it inward from the chimney, leaving large openings through which cold air entered. Consequently the published results of the Johns Hopkins experiments would have to be used with a considerable measure of caution as they did not represent good chimney conditions.

While there were many variables involved in chimney design, Professor Christie concluded, all but a few were unimportant and could be neglected. Certain definite items such as velocity, mean temperature difference, and friction loss could be determined, and then three or four of the important variables might be selected and some real experimental data obtained on them which would make it possible to design a chimney with a reasonable degree of accuracy.

F. F. Uehling[6] said that air infiltration between the boiler and stack, though not given much thought, was a serious matter. In the majority of the plants which he had had occasion to examine in this regard he had found that the CO_2 percentage at the base of the stack ranged from 3 to 5 per cent. When the gases left the boiler the percentage was from 10 to 12, which meant a tremendous infiltration of air, in fact, so much so that the stack was burdened with 100 per cent more gas than it should carry away.

Others who briefly commented on the paper were Max Toltz,[7] who welcomed the new method as one that would make it possible to design stacks rapidly and with accuracy; and W. B. Frost, who believed that the new types of airtight flues would do away with much of the uncertainties in design caused by air infiltration.

(Continued on page 569)

[2] Ch. Engr., Green Engrg. Co., E. Chicago, Ind Mem. A.S.M.E.
[3] Engr., Philadelphia Elec. Co., Philadelphia, Pa. Mem. A.S.M.E.
[4] Operating Engr., Philadelphia Elec. Co., Philadelphia, Pa. Mem. A.S.M.E.
[5] Prof. Mech Eng., Johns Hopkins University, Baltimore, Md. Mem. A.S.M.E.
[6] Pres. & Combustion Engr., Uehling Instrument Co., Paterson, N. J. Mem. A.S.M.E.
[7] Mech. Engr., Toltz, King & Day, Inc., St. Paul, Minn. Past Vice-Pres., A.S.M.E.

Tables and Diagrams for Water Vapor Computed on the Basis of Its Specific Heat

By DR. OSCAR KNOBLAUCH, E. RAISCH, and H. HAUSEN

EQUATIONS showing the variation of specific heat c_p with pressure and temperature have been available for many years, but all attempts to derive the general properties of steam from its specific heat by purely analytical means so as to cover by one general expression the wide range of conditions, have hitherto failed.

The present investigators claim to have derived an equation for the specific heat c_p of a simple character, with pressure and temperature entering as magnitudes of the first power only. Moreover, from the equation for c_p they have derived an equation of state as well as equations for entropy and heat content and have shown that the steam tables computed from the specific heat of steam with some auxiliary values are in good accord with tables derived by other means and values determined experimentally.

Equation for Specific Heat of Steam c_p

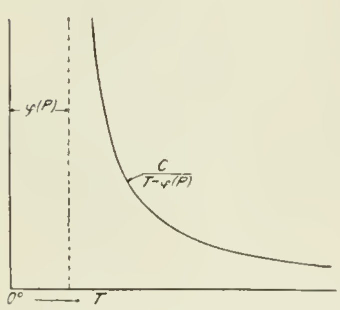


Fig. 1 Geometrical Expression for the Second Member on the Right-Hand Side of Equation [1]

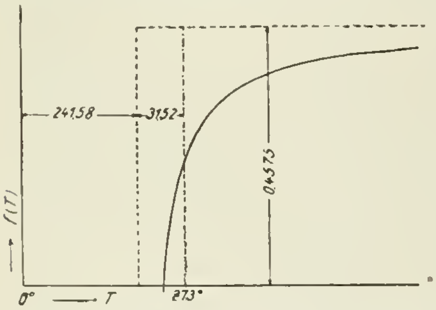


Fig. 2 Geometrical Expression for the Temperature Function $f(T)$ in Equation [1]

The present work is based on recent determinations of the specific heats of water vapor carried out by Knoblauch and Raisch at the Munich Technical High School. These values are given in a diagram in the original publication. In this the temperatures are plotted as abscissas and the c_p values as ordinates. Curves are then drawn through points thus obtained experimentally, connecting points of equal pressure (c_p isobars). It has been found that these c_p isobars are hyperbolic in their curvature, the position of the asymptotes varying with the pressure. This is expressed by the equation

$$c_p = f(T) + \frac{C}{T - \varphi(p)} \quad \text{[1]}$$

where $f(T)$ is a pure temperature function, $\varphi(p)$ a pure pressure function, and C a constant. A somewhat similar equation for c_p was proposed some years ago by R. Plank, but a pressure function was employed instead of the constant C and the temperature function was referred to the specific heat c_p at the pressure $p = 0$.

The selection of the functions involved and the constant C had to be made in such a manner that on the one hand Equation [1] would give for the specific heat c_p values agreeing with those obtained experimentally within the region from 0.5 to 20 atmos.; and on the other hand, would give also by extrapolation correct values for c_p at the critical pressure and at the pressure $p = 0$. In order to satisfy general thermodynamic requirements c_p must become equal to ∞ at the critical point, i.e., the critical temperature $t_k = 374$ deg. cent. and the critical pressure $p_k = 225.05$ atmos.

The constant C and the functions $f(T)$ and $\varphi(p)$ were determined

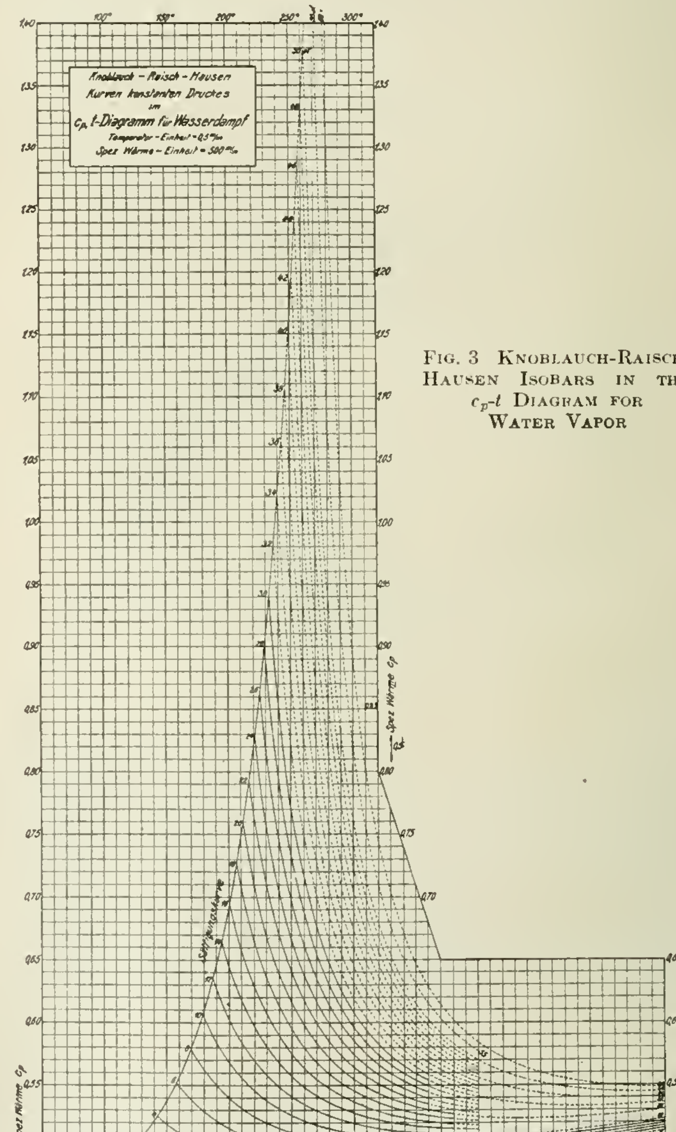


Fig. 3 Knoblauch-Raisch-Hausen Isobars in the c_p-t Diagram for Water Vapor

first by trial and then by the method of least squares, this being done on the assumption that $T = 273.1 + t$. This gave

$$C = 20.33 \quad \text{[2]}$$

$$\varphi(p) = 588.97 + 0.37354\,p - \frac{6310.3}{18.165 + p} \ldots\ldots [3a]$$

with p expressed in kilograms per square centimeter, or

$$\varphi(P) = 588.97 + 0.37354\,[P \times 10^{-4}] - \frac{6310.3}{18.165 + [P \times 10^{-4}]}\ [3b]$$

with P expressed in kilograms per square meter. For the region of temperature above 100 deg. cent. and also between 50 and 100 deg. cent.,

$$f(T) = 0.3391 + 0.000197T - \frac{12.8}{T - 256.4} \ldots\ldots [4a]$$

and below 100 deg. cent.

$$f(T) = 0.4575 - \frac{20.33}{T - 241.58} \ldots\ldots [4b][1]$$

If instead of absolute temperatures the temperatures in degrees centigrade be used, counting from the freezing point, Equations [4a] and [4b] read, respectively,

Above 100 deg. cent.: $f(t) = 0.3929 + 0.000197\,t - \dfrac{12.8}{t + 16.7}$ [5a]

Below 100 deg. cent.: $f(t) = 0.4575 - \dfrac{20.33}{t + 31.52} \ldots\ldots [5b]$

Equation [1] for c_p after substituting the values given above for $f(T)$, $\varphi(p)$, and C will then read as follows:

For temperatures above 100 deg. cent.:

$$c_p = 0.3391 + 0.000197T - \frac{12.8}{T - 256.4} + \frac{20.33}{T - 588.97 - 0.37354p + \dfrac{6310.3}{18.165 + p}} \ldots [6a]$$

or

$$c_p = 0.3929 + 0.000197t - \frac{12.8}{t + 16.7} + \frac{20.33}{t - 315.87 - 0.37354p + \dfrac{6310.3}{18.165 + p}} \ldots [7a]$$

and for temperatures below 100 deg. cent.:

$$c_p = 0.4575 - \frac{20.33}{T - 241.58} + \frac{20.33}{T - 588.97 - 0.37354p + \dfrac{6310.3}{18.165 + p}} \ldots [6b]$$

$$c_p = 0.4575 - \frac{20.33}{t + 31.52} + \frac{20.33}{t - 315.87 - 0.37354p + \dfrac{6310.3}{18.165 + p}} \ldots [7b]$$

These equations give with great precision the values experimentally obtained by Knoblauch and Raisch for c_p. A valuable feature is that they contain pressure and temperature in the first power only, which permits the use of the slide rule in computations. In this connection it may be noted that Equation [1] admits of geometrical interpretation. Its second member $\dfrac{C}{T - \varphi(p)}$, when considered as a function of T, gives at constant $\varphi(p)$ an equilateral hyperbola, of which one asymptote is constituted by the axis of abscissas (axis of temperatures) and the other by a line parallel to the axis of ordinates and located therefrom at a distance $\varphi(p)$. For different pressures the distance $\varphi(p)$ varies, and therefore for various pressures we have a series of congruent equilateral hyperbolas differing from each other through being displaced in a horizontal direction.

The temperature function $f(T)$ may be likewise represented in accordance with Equation [4b] by an equilateral hyperbola, so that in accordance with Equation [1] the specific heat may be obtained by "additions" of hyperbolas.

From this expression for the specific heat of steam the authors proceed to derive various other equations. Because of lack of space it is impossible to give the derivations and only the equations themselves will be reproduced here.

Equation of State—Entropy and Heat-Content Equations

The equation of state is as follows:

$$v = \frac{RT}{P} - \frac{C\varphi'(P)}{A[\varphi(P)]^2}\left[T \log \frac{T}{T - \varphi(P)}\right] - \varphi(P) + \psi(P)\ [8]$$

where

$$\psi(P) = -0.01151 + 0.0000257\,[P \times 10^{-4}] + \frac{0.438}{15.3 + [P \times 10^{-4}]} \ldots [9]$$

It is of interest to note that the second and third members on the right-hand side of Equation [8] represent the deviation of steam from the ideal gas state.

[1] No explanation is given as to which of the two equations, ([4a] and [4b]), should be applied between 50 and 100 deg. cent.

TABLE 1 STEAM TABLE COMPUTED FROM TEMPERATURE

1 Temperature, deg. cent. t	2 Absolute temperature, deg. cent. T	3 Absolute saturation pressure, kg. per sq. cm. p_s	4 Specific volume of saturated steam, cu. m. per kg. v''	5 Specific weight of steam, kg. per cu.m. γ''	6 Heat content of liquid, kg-cal. per kg. i'	7 Heat content of steam, kg-cal. per kg. i''	8 Total heat of evaporation, kg-cal. per kg. $i'' - i' = r$	9 Sensible heat of evaporation, kg-cal. per kg. $AP_s(v'' - v')$	10 Latent heat of evaporation, kg-cal. per kg. $\rho = r - vAP_s \times (v'' - v')$	11 Entropy of liquid, kg-cal. per deg. cent. per kg. s'	12 Entropy of steam, kg-cal. per deg. cent. per kg. s''	13 $s'' - s' = r/T$	14 Temperature, deg. cent. t
125	398.1	2.3670	0.77046	1.2979	125.5	648.6	523.1	42.66	480.4	0.3781	1.6926	1.3145	125
130	403.1	2.7549	0.66830	1.4963	130.6	650.2_5	519.6_5	43.06	476.6	0.3908_5	1.6803_5	1.2895	130
135	408.1	3.1915	0.58212	1.7179	135.7	651.8	516.1	43.44	472.7	0.4034_5	1.6684	1.2649_5	135
140	413.1	3.685	0.50857	1.9663	140.8_5	653.3_5	512.5	43.81	468.7	0.4159	1.6568	1.2409	140
145	418.1	4.238	0.44591	2.2426	146.0	654.8	508.8	44.16	464.6	0.4382_5	1.6454	1.2171_5	145

TABLE 2 STEAM TABLE COMPUTED FROM PRESSURE

1 Absolute pressure, kg. per sq. cm. (atmos.) p	2 Saturation temperature, deg. cent. t_s	3 Absolute temperature, deg. cent. T_s	4 Specific volume of saturated steam, cu.m. per kg. v''	5 Specific weight of saturated steam, kg. per cu.m. γ''	6 Heat content of liquid, kg-cal. per kg. i'	7 Heat content of steam, kg-cal. per kg. i''	8 Total heat of evaporation, kg-cal. per kg. $i'' - i' = r$	9 Sensible heat of evaporation, kg-cal. per kg. $AP_s(v'' - v')$	10 Latent heat of evaporation, kg-cal. per kg. $\rho = r - AP_s \times (v'' - v')$	11 Entropy of liquid, kg-cal. per deg. cent. per kg. s'	12 Entropy of steam, kg-cal. per deg. cent. per kg. s''	13 $s'' - s' = r/T_s$	14 Absolute pressure, kg. per sq.cm. (atmos.) p
2.0	119.61	392.71	0.90221	1.1084	120.0	646.9	526.9	42.26	484.6	0.3643	1.7062	1.3419	2.0
2.5	126.78	399.88	0.73201	1.3661	127.3	649.3	522.0	42.81	479.2	0.3827	1.6881	1.3054	2.5
3.0	132.87	405.97	0.61698	1.6208	133.5	651.2	517.7	43.28	474.4	0.3981	1.6735	1.2754	3.0
3.5	138.18	411.28	0.53375	1.8735	139.0	652.8	513.8	43.67	470.1	0.4114	1.6610	1.2496	3.5
4.0	142.91	416.01	0.47082	2.1240	143.8	654.2	510.4	44.01	466.4	0.4231	1.6501	1.2270	4.0
4.5	147.19	420.29	0.42159	2.3720	148.3	655.4	507.1	44.33	462.8	0.4336	1.6405	1.2069	4.5

The entropy equation is

$$s = s_c + \int \frac{f(T)}{T}\, dT - \frac{C}{\varphi(P)} \log \frac{T}{T - \varphi(P)} - AR \log P \quad [10]$$

where s_c has the average value of 0.73279.

The equation for the heat content is

$$i = i_c + \int f(T)dT + C \log\,[T - \varphi(P)] + A \int \psi(P)dP \ldots [11]$$

The notation for Equations [8] to [11] is as follows:

- t = temperature in deg. cent. counting from the freezing point
- T = absolute temperature in deg. cent. = $273.1 + t$
- A = 1/426.9 = reciprocal of the mechanical equivalent of heat
- R = 47.10 = gas constant of water vapor
- u = internal energy in kg-cal. per kg.
- v_0, u_0, s_0 and i_0 = respectively, the specific volume, internal energy, entropy, and heat content at 0 deg. cent. and the corresponding saturation pressure $(p_s)_0$ = 0.006226 atmos.
- v', u', s' and i' = corresponding values for liquid water at temperature t_s corresponding to saturation pressure p_s
- v'', u'', s'' and i'' = corresponding values for dry saturated steam.

The original publication discusses in some detail the process as employed in making the theoretical calculations and presents a comparison of the steam tables computed from the values of the specific heat with the results of direct observation.

Conclusions Arrived at by the Authors

A comparison of the steam tables with thermodynamic deductions and results of observations leads the authors to the following conclusions:

1 It follows from theoretical considerations that for the critical state $c_p = \infty$; actually this value is obtained from Equation [1] for $t_k = 374$ deg. cent. and $p_k = 225.05$ atmos.

2 The heat content of water vapor at constant temperature decreases with increase of pressure. This is actually found to be the case in the i-s and i-p isotherm diagrams.

3 The following remarks are made in reference to the extent of further numerical control of steam tables. Equation [10], derived to express entropy s, contains in addition to the thermodynamically established relation between c_p, pressure, and temperature only the constant of integration s_c. In this equation, therefore, apart from this quantity s_c, the experimentally established behavior of the c_p values is expressed in its purest manner. This makes the computations carried out in connection with the values of entropy all the more valuable.

Now, if we connect by means of

$$(s'' - s')T_s = r \ldots\ldots\ldots\ldots [12]$$

the values of s'' computed in accordance with Equation [10] with the experimentally determined values of s' and T_s, we obtain the heat of vaporization r. The authors give for purposes of comparison the values for r experimentally determined by Henning and in a parallel column those computed from the Clausius-Clapeyron equation. The differences between the two sets of values are very slight, however, which is particularly interesting in view of the fact that these two sets of values have been obtained in entirely different ways which are independent of each other.

The original publication contains steam tables computed from the specific heat. Of these only two are reproduced here on account of lack of space. (*Tabellen und Diagramme für Wasserdampf berechnet aus der spezifischen Wärme*, Verlag R. Oldenbourg, Berlin, 1923, 32 pp., illustr. *etA*)

An Investigation of Welded Pressure Vessels

An EXTENSIVE PUBLICATION which may be divided into three parts, namely: a report of tests carried out by the Bureau of Standards; an analysis of test data given in this report and comments on the various features considered; and finally, recommendations made by the Pressure Vessel Committee of the American Bureau of Welding for the consideration of the Boiler Code Committee of The American Society of Mechanical Engineers in their revision of the Code for Unfired Pressure Vessels.

As regards the report of the Bureau of Standards, it deals with an investigation of strength of welded pressure vessels. As it is expected that it will be published by the Bureau in the usual manner, at which time it will be available at a very low cost to all those interested in the subject, only the conclusions arrived at are reported here. These are:

1 The double V-weld is much superior to the single V-weld.

2 The pipe shells tested were less uniform and averaged lower in strength than double V-welded plate shells.

3 The butt-welded heads were stronger than the inserted heads.

4 A hammer test cannot be relied upon to show more than a very few exceptionally defective welds.

5 The hammer test, as applied, apparently did not weaken the tanks.

6 Hydrostatic pressure 1½ times the working pressure showed only a small number of imperfected welds, even when the hammer was used.

7 Hydrostatic pressure sufficient to stress the shell to the yield point will show a large proportion of imperfect welds.

8 Hydrostatic pressure sufficient to produce a permanent set in the shell, enlarging the circumference ½ per cent, apparently does not weaken the tank.

9 Flanges for inspection plugs can be welded in the heads of a tank without weakening it.

The comments on the report of the Bureau of Standards fall into several sections. In those dealing with construction it is pointed out among other things that there is one principle which it is felt should be carried out in all welded steel structures of importance, which is that the included V-angle should not be less than 90 deg.

The shells in these tanks were crimped over the heads, a construction that is thought by many to give added strength. There is some doubt, however, as to its effectiveness, though this must increase as the diameter of the tank decreases, the thickness of the shell and the amount of crimping being the same. The drawing of these tanks submitted by their maker shows such an amount of crimping as to make the V-angle so small that it is quite impossible to make the weld as indicated. The photograph of the actual sections shows this to be true, and it seems clear that, considering the small amount of weld metal actually holding, and the fact that there is bad bending action in the weld, the very high factor of safety is all that saves the construction from failure, and so the design cannot be commended. It is believed that other designs, more efficient, and probably just as cheap, are available, and that they should be used in the interests of safety. Of course there can be no objection to the use of pipe for the shell with a proper factor of safety, and with flanged heads butt-welded to the shell the construction would be beyond criticism.

In one of the tanks tested, in fact, the strongest of the lot, it was found that there was a severe strain on the head weld caused by its rigidity which kept it from bending while the material on both sides of it could distort. In another instance one of the head welds cracked under the hammer test.

The maker reports that during the 50-lb. hydrostatic shop test for tightness there were found two damp spots, one in each head seam, which were rewelded, and after retest were found tight. It is not possible now to identify these spots, but the crack may be at one of them.

This rewelding might account for a local stress, which, added to the test stress, might be of sufficient amount to cause local rupture. It is a very good illustration of what may occur if enough care be not taken in making repairs.

There are three points to note in this connection:

1 The static test at $1\frac{1}{2}$ times the working pressure did not detect the defect.

2 The defect was found by the hammer at a lower pressure than $1\frac{1}{2}$ times the working pressure.

3 The crack was evidently caused by local internal stresses because (*a*) it occurred at low pressure and (*b*) it was local.

So far as this case is concerned, it seems clear that something more than a static test is needed, and that a shock of moderate amount while the tank is under moderate pressure will show up defects not revealed by a static pressure of the same or somewhat greater amount.

It is probably a good thing that this tank failed as it did, as it shows that the Code provision for a reweld and retest is safe practice if the work is properly done. It is also evident that local stresses can exist in otherwise properly welded tanks, and that they have no effect on the strength of the rest of the welds.

Design

It is claimed that the best method for applying heads is by butt-welding a flanged head to the shell, and where a head convex to the pressure is used the method in the Code should be followed.

As regards the question of what fiber stress should be used in designing unfired pressure vessels, the conclusion is reached that it seems quite fair and safe to use 50,000 lb. as the basis for design. With a factor of safety of 5, and a weld value of 80 per cent, this would mean a design fiber stress at the working pressure of 8000 lb., based on the nominal plate thickness. In view of the high efficiency of the double V-weld, 97 per cent or 9700 lb. fiber stress, using the above basis, this does not seem to the Committee excessive, unfair, or in any degree dangerous, and they therefore recommend its adoption. It would apply also to the special tanks, only 4 of the 23 having less than 50,000 lb. tensile strength.

For wrought-iron pipe used for pressure vessels a maximum working fiber stress of 4000 lb. is recommended, although it is pointed out that steel pipe is just as easy to obtain and makes the construction safer.

The Committee considers it inconsistent to allow 150 lb. for air tanks and 250 lb. for ammonia tanks. It believes that it is entirely safe to put all liquids or gases on the same basis as far as welding is concerned.

The Committee also objects to the requirement in the Code to the effect that heads convex to the pressure shall have a skirt not less than 3 in. long. This is impractical for smaller-sized heads and the Committee recommends certain relations between the length of the skirt and the diameter of the head. Also the Committee believes that the constricting or crimping of the end of the shell is unnecessary, although not objectionable. The Committee also recommends a certain form of convex head. The necessity for this is due to the fact that as heads convex to the pressure are much thicker than the shell, the welder is at some disadvantage unless the head is reduced in thickness. There are a number of other recommendations which cannot be reported here on account of lack of space.

Hydrostatic Hammer Test

A search was made by one of the Committee, but only a few references have been found, and they are merely references to the fact that it is used.

The American Society for Testing Materials provides in its specification for cast-iron pipe as follows:

SECTION 14 The straight pipes shall be subjected to a proof by hydrostatic pressure, and if required by the engineer, they shall also be subjected to a hammer test under this pressure. [No details of how the test is to be applied are given.]

The pressure to which the different sizes and classes of pipes shall be subjected are as follows:

Class	Working pressure[1]	Test Pressure 20 in. diam. & larger	Test Pressure Less than 20 in.	Fiber stress at test pressure	Fiber stress at test pressure[2]
A	43 lb.	150 lb.	300 lb.	4 in., 1420 lb. 18 in., 4200 lb.	20 in., 2230 lb. 60 in., 3230 lb.
B	86 lb.	200 lb.	300 lb.		
C	130 lb.	250 lb.	300 lb.		
D	173 lb.	300 lb.	300 lb.	4 in., 1150 lb. 18 in., 2760 lb.	20 in., 2900 lb. 60 in., 3780 lb.

[1] Added to table. [2] Calculated from data in specifications.

It will be seen that the ratio of test pressure to working pressure varies widely—from about 7.0 to 1.7—and that the fiber stresses in the table are likewise irregular and variable. The Committee is not in a position to criticize, and simply points out the variations as indicative of either unusual conditions or of lack of standardization, probably the latter.

The data and wording of the American Water Works Association specifications are identical with those of the American Society for Testing Materials.

Statements are given of methods of hammer testing cast-iron and steel pipe. From both it will be seen that the hammer used is not heavy, and, from a study of the tables of test pressures, that the fiber stresses used are not as high as in the Bureau of Standards' tests. The test pressures in the proposed revision of the A.S.M.E. Rules for Piping and Fittings are the same as those of the American Society for Testing Materials, and no hammer test is specified in either case.

On the other hand, there are data in favor of this test. One of the members of the Boiler Code Committee, who is a strong advocate of the Code test, states that in his experience it has been of much value in detecting leaks and other imperfections.

One of the members of the present Committee, who has used the hammer test for several years, states that by employing it some leaks have been found that were not shown up by the pressure alone, and he would not want to omit its use.

It has been the experience of one job welding shop, in the case of many hundreds of cast-iron vessels, ranging in size from small auto cylinders to very large heating-boiler sections, that, with a city water pressure of from 40 to 60 lb., an ordinary machinist's hammer, used in proportion to the weight of the vessel, will invariably detect a strain due to uneven shrinkage, and that if no effect is produced by the hammering, there is also invariably successful service. It has also been their practice for over five years, in cases where the working pressure is known, to use the Code test on all welded cast-iron pressure vessels, such as steam-jacketed kettles, and they state that they would not feel safe in letting them leave the shop without being so tested, and that no vessel of this type passing this test has ever failed in service.

It is their belief that the test is specially adapted to detect strains, which are serious in cast-iron welds, and that it will not, from their experience, detect an imperfect cast-iron weld unless there is a strain in it, because the factor of safety in the vessels referred to is made very high because of foundry conditions, so that even an imperfect weld will be plenty strong enough.

The statement usually made, as far as the Committee knows, is that the Code test should detect a bad weld. At once the question may be asked, What is a bad weld? The Committee knows of no attempt to evaluate or define it. There are evidently various degrees of badness in welds, as in anything else, but in the tests no "bad" weld was detected by the Code test except one (Tank X15). The other one found by it was a good weld (Tank K4), containing a local strain, which was repaired and the tank on retest broke at 50,500 lb. fiber stress. It is quite probable that X15 had a strain in the weld, due to the thin welds having to stand all the shrinkage stress.

The Committee has inquired of its members and others as to their idea of a bad weld, which would be discovered by the Code test, and has found that none of those questioned had any definite opinion on the matter.

Physical Qualities of Materials

The Code has no specifications for the pipe which was used for nine of the regular tanks tested. The Committee feels that wrought-iron pipe being naturally weak longitudinally in the tank or transversely in the skelp, is not a suitable material for pressure vessels unless the factor of safety is very high, and that lap-welded steel pipe could be used instead without any hardship.

The subject of high- or low-tensile-strength plate for welding is discussed in some detail. As regards the yield point, it is believed to be perfectly safe to allow a high yield point, especially since the material is annealed by the welding for quite some distance from the weld. This annealing increases the elongation, allowing the steel to absorb the welding strains in spite of higher tensile strength than the Code allows. From the foregoing it is safe to provide

that material $^1/_4$ in. thick or less shall have the following physical properties:

Tensile strength (T.S.), lb. per sq. in.	60,000 max.
Yield point, lb. per sq. in.	0.5 T.S. min.
Elongation, per cent in 8 in.	1,500,000/T.S.

provided that the elongation be measured on a gage length of 24 times the thickness and that the Code chemical analysis be complied with, and the Committee so recommends. The Committee believes that the use of a definite minimum for the yield point is not as good as the limit used in the Boiler Code in which the yield point is equal to 0.5 T.S. min., because the former excludes Armco iron, a very good material, while the latter admits it. Whatever form of specification is used, Armco iron should be allowed. Further, the Committee believes that if its recommendation as to hydrostatic test at three times the working pressure be adopted, the yield point minimum of 24,000 lb. is too low, as it is just three times the fiber stress, 8000 lb., of which the Committee is in favor.

Chemical Requirements of Plate

The Committee recommends the following as a specification that will fit all cases:

	Per cent max.		Per cent max.
Carbon	0.15	Phosphorus	0.04
Manganese	0.30 to 0.60	Sulphur	0.05

It is believed that there should be a low limit on the manganese, to insure good steel, and 0.30 per cent is recommended. This would exclude Armco iron, which is entirely suitable for pressure vessels, provided its low tensile strength (about 45,000 lb.) is allowed for, and its use should be permitted by some such wording as, "The use of ingot iron is permitted provided a fiber stress of 7200 lb. per sq. in. at the working pressure is not exceeded." (*Journal of the American Welding Society*, vol. 2, no. 5, May, 1923, pp. 11 to 162, 120 figs., *epA*)

Short Abstracts of the Month

AIR MACHINERY

Device for Testing Air Drills and Hammers. Description of an air-motor testing device which has recently been developed at the shops of the Pittsburgh & Lake Erie Railroad at McKees Rocks, Pa.

For testing drills a motor is mounted in the device and is guided at the drill by a cross-bar resting on a test block. Air is supplied to the cylinder through a flexible hose and valve. When the air is admitted at the top of the cylinder and exhausted at the bottom, this forces the piston down on top of the air motor at a pressure indicated by the gage, and the extent of this pressure may be regulated as desired.

For testing, the air motor is set up with a 2-in. drill point resting on the test block and pressure is applied slowly until the air motor is pulling to capacity. The revolutions per minute are counted and the pressure is noted. The pressure needed to stall the motor is also recorded and, provided the sharpness of the drill point is kept constant, this pressure is the measure of the efficiency of the air motor. Through this test one may determine whether or not a drill after being repaired has been brought back to its rated capacity.

In ascertaining the vibrations of hammers, the piston rod of the 8-in. by 14-in. air cylinder of the testing machine is chalked, and the vibrations are indicated by a pair of calipers held against the piston rod. The hammer is allowed to run for a given length of time and the vibrations are measured. This test is run to make comparisons between different types of new hammers, and it is also applied when old hammers are being overhauled, in order to find out if the vibrations have increased to any extent with the age of the pneumatic tools.

D. G. Redding, assistant superintendent of motive power of the Pittsburgh & Lake Erie Railroad, reports that some of the hammers which were said to have the least vibration have shown excessive vibration under this kind of test. He is considering modifying the machine in question in such a way that comparative capacity tests of hammers may be made with it. It is believed that this can readily be done by the aid of additional attachments. (*Compressed Air Magazine*, vol. 28, no. 7, July, 1923, p. 560, 3 figs., *d*)

BUREAU OF STANDARDS (See Refrigeration)

ENGINEERING MATERIALS

Corrosion of Condenser Tubes—Flow of Water and Air-Bubble Action

The Rapid Corrosion of Condenser Tubes, Guy D. Bengough and R. May. A brief summary of conclusions as to the cause of the rapid corrosion of condenser tubes which have been arrived at in the course of an investigation carried out during the last few years under the direction of the Corrosion Research Committee of the Institute of Metals. The full evidence has not yet been published.

The present article deals only with corrosion caused by the presence of entangled air in the circulating water in estuarine and marine conditions. The attack is especially serious, because it can cause tube failure in a few weeks or even days.

This cause is largely independent of the chemical composition of the tube, i.e., any ordinary tubes of commerce of 70 : 30 brass, Admiralty alloy, lead brass, or arsenical copper will show the action when exposed to suitable conditions. In fact, any selected area of any ordinary tube is liable, and can be made, to show the action. Certain alloys very high in nickel, e.g., containing up to 20 per cent nickel, fail as badly as brasses.

The action which produces the rapid failure has certain characteristics, of which the following is a list:

1 It usually occurs near the water inlet of the tubes in the first pass, and less frequently near the water outlet of long tubes.

2 It occurs indifferently anywhere round the circumference of the tube, and frequently all round it. A considerable area of tube is attacked, i.e., the action is not concentrated at sharply defined isolated pits.

3 A longitudinal section of a tube corroded by this action when rubbed down on an oil stone shows a characteristic "water worn" appearance, from which the direction of the flow of the water can be readily determined.

4 The tubes showing the action are often found to be spaced over a comparatively small area of the tube plate. If a corroded tube be replaced by a new tube, the latter will often again fail rapidly, and the process may be repeated several times.

5 The action is seldom shown by tubes that have been a long time in the condenser, i.e., tubes either show it in their early life or not at all.

6 Ordinary methods of electrolytic protection fail to prevent the action.

7 Metallic copper is seldom found as a corrosion product at the corroded areas; these often seem remarkably free from corrosion products.

8 Ferrules occasionally show the action. These are frequently made of 60:40 alloy, but even in such cases it often happens that no metallic copper is visible at the corroded surface.

As regards the cause of corrosion, evidence seems to indicate that the main cause of the action must be in the conditions to which the tubes are subjected. Furthermore, it has been found that not all the tubes in a single pass are always in similar conditions and behave similarly if of uniform quality. This is due to the fact that the speed at the tube wall may vary in different tubes, as has been found by the use of glass tubes.

The phenomena of flow observed in the tubes varied considerably with the type of water used in the experiments. The behavior of sea water only will be discussed in the present article. The first point of importance to be noted is that smooth flow, such as is usually assumed to take place through all condenser tubes, did not take place through many of the tubes. In certain tubes the water stream formed vortices or more or less flat or extended spirals, especially for the first 2 ft. or 3 ft. of the tube. See Figs. 3 and 4. Where these spirals impinged on the walls local turbulence

was set up as shown in Fig. 4. Some approximate measurements were made—by a photographic method—on the variations of speed that occurred at various parts of the tube. For this purpose the introduction of small solid particles of air bubbles was useful; the behavior of these showed clearly that great variations of speed could take place even in a single tube. Thus at certain parts of a tube through which water was traveling at an average speed of 6 ft. per sec., local retardation near the tube wall might reduce the speed almost to zero, while in the center of the tube the speed might approximate to twice the average speed. Turbulence prevailed in different degrees in many of the tubes for a length of 2 ft. or 3 ft. from the inlet end and then gradually died away. When turbulence prevailed high water speeds might be attained locally near the tube wall. The actual amount of water passing through a given tube was, of course, greatest in the tubes with least turbulence, i.e., with the nearest approach to smooth flow. Probably the highest speeds were developed locally in tubes with the greatest turbulence. The phenomena differed noticeably in tubes in different positions relative to the main water inlet. Some tubes showed scarcely any vortices but local impingement on the tube wall near the inlet end—as shown in Fig. 2.

An increase in the water speed increased the complexity of the phenomena; a decrease to 2 ft. or 3 ft. per sec. caused an approximation to smooth flow to take place throughout the greater part of the tube.

TABLE 1 CORROSION OF BRASS TUBES (18 W.G.)
(Duration of experiment, 28 days; temperature, 20 deg. cent.; speed of water, 10 ft. per sec.)

Alloy	Per cent penetration on 1.21 mm. = 18 W.G.	Amount of entangled air in cc. per hr.
70:30	Less than 1	0.7
70:29:1[1]	2.5	0.7
70:30	Less than 1	25
70:30	Less than 1	145
70:30	31	3,000
70:29:1	35	3,000
70:30	83	11,000

[1] Laboratory-cast specimen.

It has previously been found experimentally that an increase in water speed, at least up to about 20 ft. per sec., increases the rate of corrosion of both copper and brass; consequently, the greatest local corrosion would be expected where the greatest turbulence prevailed, i.e., near the inlet end.

Nevertheless the failure of tubes in practice in a few weeks could not be explained on the basis of high water speed alone. Even with the highest water speed used in the experiments, namely, 25 ft. per sec., a copper tube would have a life of at least six months, at laboratory temperatures.

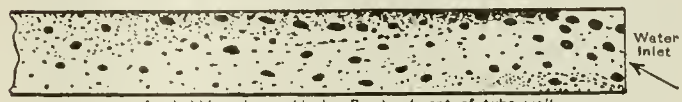
Further tests indicated that entangled air in water is the real cause of rapid corrosion. Sea water was found always to contain a small amount of air in very fine bubbles. These were evidently due to a certain amount of churning in the centrifugal pump which had caused them to pass out of solution. They retain their identity for considerable periods in this particular water for the same reasons which cause it to exhibit the familiar property of foaming, which is not possessed by many fresh waters.

Further, some comparative tests were made in which the corrosive effect of sea water containing only dissolved air in normal amounts was compared with that of the same water containing, in addition, mechanically entangled air. The results were very striking, and a few are shown in Table 1. In the case of brass condenser tubes the rate of corrosion is greatly increased when a certain small volume of entangled air is exceeded; thus with 3 liters of air per hour passing through the tubes their lives would be only about three months. These tests were carried out by impinging a jet of sea water containing air on to the surface of the tube arranged at right angles to it.

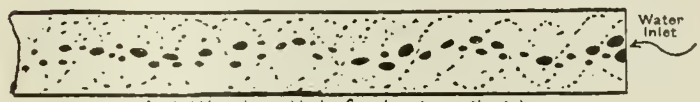
The total volume of air, however, is not the only factor in the case; another important one is its state of subdivision. A given volume of air is more harmful in a fine state of subdivision than when present in large bubbles. A fine foam appears to be the worst possible case. A foam consists of an intimate mixture of air and water, from which the air does not readily separate.

Very small amounts of certain liquids and solids can greatly stabilize foams, that is, prevent the separation of the air, e.g., certain oils and basic salts. Notable differences in the tendency to foam have been encountered between the samples of sea water collected in large stoneware jars and successively filled from the same position on a jetty; such differences may have a noticeable effect on corrosion. As a rough generalization it may be said, however, that the penetration of a tube per month by an air-sea-water jet containing three liters of air per hour in the conditions of Table 1 varies from 26 per cent to 33 per cent for the ordinary run of 70:30 tubes of commerce. With a highly foaming batch of water higher penetrations are occasionally observed, the highest yet recorded being 49 per cent. These experiments were usually carried out with sets of twelve tubes at a time, and it was clear that the varying results were due to the conditions rather than to the tubes, since if one tube gave a high result all the others in that set did so. In all cases the type of corrosion strikingly resembled that which occurs in conditions of ordinary practice.

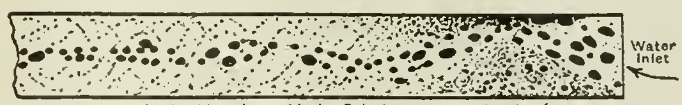
Air bubbles shown black. Nearly smooth flow, characteristic of low water speeds. Large bubbles tend to rise to top of tube. Comparativaly harmless form of flow.



Air bubbles shown black. Bombardment of tube wall near end of tube Produces heavy corrosion on top half of tube, and less corrosion on bottom half owing to the existence of eddies.



Air bubbles shown black. Spiral motion without bombardment of tube wall. Comparatively harmless form of flow



Air bubbles shown black. Spiral motion and bombardment of tube wall The worst condition for corrosion The spirals "flicker" all round the tube and produce corrosion irregularly anywhere or all round the wall.

Figs. 1 to 4 Behavior of Water Containing Entangled Air in Glass Condenser Tubes

A small amount of sulphuretted hydrogen in the water, such as is occasionally found in conditions of practice, greatly enhances the rate of attack; thus, with sea water containing 3 cc. of the gas per liter, penetrations of 82 per cent and 90 per cent per month of twenty-eight days have been recorded in the conditions of Table 1.

The reason for the peculiar distribution of the corrosion on tubes suffering from the rapid type of action described at the beginning of this article may now be suggested. It will be remembered that the position at which the action is usually worst is the first two or three feet of the tube at the inlet end. It is just at this position that turbulence and impingement of air on the tube wall are worst; here the tube suffers from an intermittent bombardment with air bubbles, as shown diagrammatically in Figs. 2 and 4. Further along the tube the turbulence dies out and corrosion falls off. The remarkable observation has been made, however, that the size of the bubbles gradually decreases, and toward the end of a long tube, i.e., 15 ft., much of the air appears to be distributed as a fine "mist" of air in water; i.e., in just the state in which it is most harmful. So fine is this mist that with an average speed of 7.5 ft. per sec. through the tube no tendency for the bubbles to rise to the top of the tube could be seen. Any roughening of the tube surface by local scale accumulation or otherwise, or any obstruction in the tube will be liable to cause local eddies and local air bombardment, and consequently give a chance for corrosion to start.

A simple method of reducing the trouble is suggested, namely, to use for replacements Admiralty tubes that have been heated to 40 deg. cent. for a week in sea water, which should be stagnant

or only slowly moving. If this cannot be done, then tubes from other parts of the condenser in which failures are known to be few should be used for replacements, and new tubes inserted in the positions thus vacated. This procedure will often require tubes to be moved from the second pass to the first in two-pass condensers, and will be most effective if proper records of failure are kept. (*The Engineer*, vol. 136, no. 3523, July 6, 1923, pp. 7–10, 15 figs., *eA*)

Report on Researches on the Chemical and Physical Properties of Insulating Oils. The Research on Insulating Oils was initiated by the Institution of Electrical Engineers, continued by the Electrical Research Committee, and transferred to the British Electrical and Allied Industries Research Association.

The subject has been growing in importance in view of the increasing size and greater demand put upon transformers and oil switches, and would appear never to have received the thorough investigation it deserved. The results of the research should be of considerable assistance to designers and users of transformers and oil switches.

The sludging test is the most important test of the series. The prime object of the research on sludging was to ascertain by a series of tests carried out by different laboratories upon one and the same set of oils and using a selected method of test, whether a sludging test was suitable for standardization purposes in preparing purchasing specifications for insulating oils. This includes the question of rapidity, ease of performance, concordance of results between duplicate tests and between different experimenters; also the degree of accuracy to which the determination can be performed and the discovery of any possible improvement in the method itself.

Among other things it was concluded that driers containing lead or cobalt, or manganese resinates or acetates, are liable to increase the quantity of sludge formed by an oil. For this reason the use of paints or varnishes containing these driers should be reduced to a minimum if employed at all.

The article is of interest not only in view of the results obtained but also because of the description of the methods used for the various tests, such as determination of viscosity of oils, specific heat, latent heat of evaporation, vapor pressures, action of catalyzers, etc. (*The Journal of the Institution of Electrical Engineers*, vol. 61, no. 319, June, 1923, pp. 661–674, 6 figs., *e*)

Cement in Sea Water

The Disintegration of Cement in Sea Water, Wm. G. Atwood and A. A. Johnson. This paper is of interest as it gives in addition to engineering considerations the history and literature of the subject.

Among other things is discussed the so-called "ciment fondu," or cast cement, recently developed in France, the particular feature of which is the presence of alumina. This cement was widely used during the world war for the construction of gun platforms and the like where its quick-hardening qualities were of great value. One of the disadvantages of this cement is its cost, which is about double that of portland cement.

The authors arrive at the following conclusions:

1 Practically all skilled experimenters with hydraulic binding agents for the last 100 years have agreed that the primary cause for the disintegration of mortar and concrete in sulphate-carrying waters such as sea water and many alkali waters is the attack on the free lime in the mortar by the sulphates of the water.

2 The majority of the authorities agree that this disintegration can be prevented by the addition to standard portland cement of a properly constituted siliceous material which, by combination with the free lime released in the process of setting, will form a cementing material insoluble in sulphate-bearing water.

3 The high-alumina cements attain the same results by different means which appear to be just as effective. Thus far the cost of the high-alumina cements seems to be greater than that of portland, whereas the addition of silica to portland should result in a cheaper product. Considering the greater strength of the alumina cements, it is possible that the cost per unit (1 lb. per sq. in.) of strength may not be very different.

4 The use of a single standard specification for the binding agent in all structures, whatever the service conditions, does not seem to be desirable or efficient.

The purpose of the writers in collecting the information presented was to develop for their own use the necessary data for planning a comprehensive system of tests, which it is hoped may be conducted under the direction of the Committee on Marine Piling Investigations of the National Research Council. These tests, in their opinion, should be planned with consideration of the following points:

a In view of the great volume of previous research work and the general agreement in the results obtained, it seems unnecessary to make further tests to determine the causes of the failure of concrete in sulphate-bearing waters, particularly in view of the comprehensive study now being made at the University of Saskatchewan under the auspices of the Engineering Institute and the Research Council of Canada.

b Properly planned accelerated laboratory tests will give correct information as to the durability of the various binding agents within a comparatively short time. These tests should be checked by service tests which will require many years, but there seems to be no question as to the correctness of laboratory results.

c Thorough tests should be made of standard American portland cements strengthened by the addition of siliceous materials. These tests should be for the purpose of determining the necessary qualities to be possessed by the silica; proper proportions for the mixture with cements of various compositions, and the development of the most efficient and practicable methods of mixing.

d Similar tests should be made of the high-alumina cements. In this case the method of manufacture seems to be of the greatest importance. The most desirable chemical composition of the limestone and bauxite to be used for the manufacture of this type of cement should be determined more definitely than it has been.

The writers realize that many causes contribute to the failures of structures in sulphate-bearing waters and that much work has been done which has resulted in a longer life for these structures. They do not believe that the improvements resulting from previous experiments on methods of construction have solved the difficulty, nor that it will be solved until a cement immune from attack by sulphate-bearing waters is developed. (*Engineering World*, vol. 23, no. 1, July, 1923, pp. 25–31, 2 figs., *ph*)

FUELS AND FIRING

Melting Point of Coal Ash

The Melting Point of Coal Ash, F. S. Sinnatt, A. B. Owles, and N. Simpkin. This paper gives the literature of the subject and describes an apparatus for determination of the melting point of coal ash.

The melting point of the ash from vitrain, durain, clarain, and fusain from certain seams has been determined.

The melting point of the ash from different horizons in a seam is shown to vary within wide limits.

Different commercial grades of coal from the same seam may yield ashes, the melting points of which differ.

Certain bands in a seam may yield ash of very high melting point.

Chemical analysis is of little value as a criterion of the melting point of an ash.

Table 2 shows the melting point of the ash from certain commercial varieties quoted to indicate the order of the differences to be expected. It must be recognized that the slack and fine coal may not always yield ashes, the melting points of which are lower than the melting point of the ash from the lump coal from the same seam. Furthermore, the variations met with in the different grades are influenced to a large extent by the mode of occurrence of what may be called the "fortuitous" inorganic matter, and by the method of purification through which the coal passes prior to placing it on the market.

In Table 2 the slack and slurry are "washed coals." In all the other experiments the coal was unwashed.

TABLE 2 MELTING POINT OF COAL ASH IN DEG. CENT.

Seam	A	B	C
Grade of coal:			
Lump	1345	1280	1345
Slack	1240	1240	1300
Slurry	1190	1200	1189

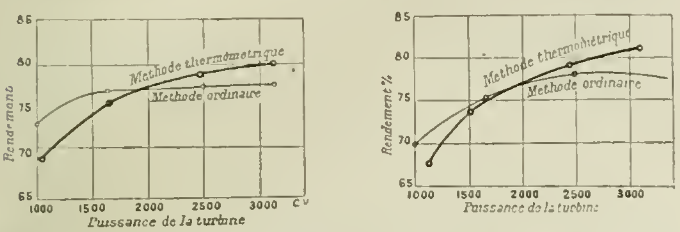
(Paper read before the Manchester Section of the Society of Chemical Industry and abstracted through the *Journal of the Society of Chemical Industry, Chemistry and Industry*, vol. 42, no. 25, June 22, 1923, pp. 266T–271T together with discussion 271–272T, 3 figs., *cp*)

HYDRAULIC ENGINEERING

Determining Efficiency of Hydraulic Turbines from Temperature Differences of Water

Calorimetric Method for Determining the Efficiency of Hydraulic Turbines. Barbillion and Poirson have recently developed a novel calorimetric method for determining the efficiency of hydraulic turbines that is remarkable for its simplicity, consisting as it does in merely measuring the difference in temperature of the water entering and leaving the turbine and the head employed.

Assume that a hydraulic turbine working at a given rate is sup-



Figs. 5 and 6 Tests of Turbines No. 1 (left) and No. 2 (right) of the Fully Plant by the Thermometric and Ordinary Methods

(*Rendement* = efficiency; *puissance de la turbine* = turbine output; *méthode thermometrique* = thermometric method; *méthode ordinaire* = ordinary method.)

plied with Q liters of water per sec. falling from a height of H meters as read on a manometer. The power delivered to the turbine will then be $P = QH$ kg-m. per sec.

Assuming that the various losses of energy in this turbine are all totally converted into heat and that the latter is carried off by the water itself, the heating of the water, which is the difference between the temperature θ_1 at the entry to and the temperature θ_2 at the discharge from the turbine, will then be proportional to the losses p, which can be written as

$$p = 427\ Q\ (\Theta_2 - \Theta_1) \text{ kg-m. per sec.}$$

The efficiency is then

$$\eta = \frac{P - p}{P} = \frac{QH - 427Q(\Theta_2 - \Theta_1)}{QH}$$

or

$$\eta = \frac{H - 427(\Theta_2 - \Theta_1)}{H} = 1 - \frac{427(\Theta_2 - \Theta_1)}{H} \text{ kg-m. per sec.}$$

This equation is notable from the fact that the discharge Q, which is the magnitude most difficult to measure, is entirely eliminated and the value of the efficiency can be obtained instantly by reading the difference of temperatures and the manometric pressure.

On the other hand, the thermometers must be simple and capable of reading temperature differences of the order of $^1/_{100}$th of a degree centigrade. There are today, however, thermoelectric devices which permit reading such temperatures with certainty.

Some have questioned the accuracy of this method on the ground that there might be other causes that would bring about differences of temperature. In this connection Figs. 5 and 6 are of interest, as they show the results obtained by the ordinary method and by the thermometric method in tests on two turbines of the Fully plant functioning with the highest head in the world. The two methods appear to give fairly close results at very large outputs, and at outputs in the neighborhood of 1800 to 1900 hp. the results coincide.

The calorimetric method is of particular value in cases where it is desired not so much to determine the actual efficiency of a plant as to control variations of efficiency, for which latter purpose it provides a simple means. (*Le Génie Civil*, vol. 82, no. 25, June 23, 1923, pp. 604–605, 2 figs., *de*)

INTERNAL-COMBUSTION ENGINEERING

Bethlehem Diesel Engine and Lowe Burner—Application to Motor Vehicles

The New Bethlehem Diesel Engine. Description of two forms of a new type of Diesel engine now under construction at the Potrero Works of the Union Plant of the Bethlehem Shipbuilding Corporation (Pacific Coast).

Two engines of the three-cylinder 150-hp. type are being built for use in the company's power plant where they will be put through a series of tests. A single-cylinder engine of this design has been running on the test stand at the Potrero Works for about three months, including a 14-day non-stop run on full load. The particular feature of this engine is the low-pressure system of oil burning without outside artificial aid in ignition. This is accomplished through the Lowe burner, for which the Bethlehem Shipbuilding Corporation has purchased the manufacturing rights.

This burner consists of a simple check valve in combination with an oil-burning tip. The tip is located in a recess in the cylinder head and surrounded by a double sleeve valve of thin polished steel, so shaped and positioned that all radiant heat which may be contained in the inner steel shell is focused on the minute drop of oil at the burner tip. The stored heat of compression in the cylinder, and the heat of combustion of the fuel oil itself added to the heat of compression, insure ignition at the moment of injection of the oil. The single-cylinder test engine referred to above was operated at compression pressures around 250 lb. Its cylinder stroke and bore are 12 in. and 8 in., respectively, and on all of its tests under all conditions of load the engine is said to have never missed a shot after starting.

The mechanical design of the engine is for two-cycle combustion, and in the experimental engine a scavenging air pressure of about $3^1/_2$ lb. was provided by crankcase compression. In the three-cylinder unit an extra cylinder is installed for scavenging air.

One feature of the Lowe system of burning oil in the engine cylinders of the two-cycle type is the by-passing of a part of the scavenging air from the scavenging-air manifold to the top of each cylinder, where this air is induced through a small check valve. This method of handling the scavenging air seems to aid in keeping the engine cool under running conditions. The test engine at the Potrero Works shows an exhaust temperature never exceeding 260 deg. fahr. A comparatively small amount of circulating water is used and the water seldom rises higher than 140 deg. at the outlet.

Certain features are of interest. Thus, the only fit between the cylinder head and the cylinder is between the shoulder on the head and the cylinder bore where a small, light copper gasket is squeezed in between the chamber on the bore and the 45-deg.-angle corner of the shoulder. There is no opening in the castings for water circulation from the cylinder walls to the head. Water circulation between these two is arranged on the outside by a simple pipe connection.

Control of the firing of cylinders is arranged entirely through the fuel pump. The fuel pump is operated by means of an adjustable block link actuated by a rolling-contact lever, which in turn is actuated by a camshaft. Through a spiral slot on this camshaft it is possible by manual control to twist the cams 180 deg. and reverse the engine. Through a manual adjustment of the block in the link any number of variations in the stroke of the fuel pump from zero to maximum can be easily obtained. This block is under control by compact form of centrifugal governor, and satisfactory regulation of the speed of the test unit has been obtained.

The engine is very light, the heavy-duty type weighing approximately 106 lb. per shaft hp. This brings it close to the range of automobile-engine design. In fact, the original article shows a four-cylinder two-cycle 50-hp. motor expressly designed for installation on a five-ton truck. This engine is now under construction at the Potrero Works. The compression pressure will be from 200 to 250 lb. with the engine running at 1200 r.p.m. The bore and stroke are 4 in. and 7 in., respectively. The minuteness of the quantity of oil used on each stroke of the engine is indicated by the dimensions of the pump, in which the plungers are $^1/_2$ in. in diameter and have a maximum stroke of $^1/_8$ in. Careful design has been necessary in laying out the link diagrams for the control mechanism, so as to give positive control of the pump-plunger

actuating links. The entire speed control of the engine is from foot or hand throttle adjustment of the block on a modified Stephenson link actuated through rolling-contact levers worked by the camshaft. (*Western Machinery World*, vol. 14, no. 7, July, 1923, pp. 215–217, 3 figs., *d*)

LUBRICATION (See Engineering Materials)

POWER-PLANT ENGINEERING (See also Engineering Materials, Railroad Engineering)

LaBelle's Giant Uniflows. Data and description of two engines now under construction at the LaBelle plant of the Wheeling Steel Corporation. These engines are of the reversing type with Marshall link and will use steam at 220 lb. pressure and 150 deg. superheat. One of them is to drive the 40-in. blooming mill now building. The other engine, with flywheel addition, will drive the 19-in. continuous mill. Each engine has four cylinders 36 in. by 60 in. and at 75 r.p.m. will develop 13,000 hp. (*The Blast Furnace and Steel Plant*, vol. 11, no. 6, June, 1923, p. 303, 1 fig., *d*)

Machinery for Mixing Fuel Automatically. Description of an installation at the coaling station at South Junction near Plattsburg, N. Y., of the Delaware & Hudson Railroad, where the mixing of mine-run bituminous coal with pea anthracite coal is effected with simple equipment.

The operations of receiving the coal in the track hopper, the feeding of uniform charges into an elevating bucket, and the delivery of the bucket to the point of dumping over the top of the storage bin have remained the same as before. The only change has been to provide two track hoppers, one for receiving the anthracite coal and the other for the bituminous coal, Shraeder automatic measuring feeders, by means of which the coal is delivered to the elevating bucket, being made to serve as the proportioning devices for mixing the coal. The bucket itself is utilized as a receptacle for the receipt of the mixture from the two feeders.

To provide means of varying the proportions, two Shraeder measuring feeders were equipped with diaphragms or vanes made to swing out from one of the walls so as to cut off a portion of the volume of the chamber and thus change the amount of coal of one kind or another being delivered to the elevating bucket. The position of this diaphragm is controlled by a screw provided with suitable calibrations so that the proportions of the mixture may be controlled at will. The operation does not vary from the usual arrangement. The elevating bucket, which has a capacity of three tons, descends between the two track hoppers and in so doing opens the two measuring feeders, causing the two grades of coal to flow from each side at the same instant and effect a thorough mixture.

The plant operates at the rate of 75 tons per hr., performing the operations of both mixing and crushing. The proportions of the mixing can be modified from a ratio of 65 per cent bituminous coal and 35 per cent anthracite to a ratio of 25 per cent bituminous and 75 per cent anthracite. The plant is equipped with a Roberts & Schaefer direct-connected spur-gear-driven electric hoist connected to a 25-hp. General Electric motor equipped with solenoid brakes. A Cutler-Hammer automatic controller provides for the continuous ascent and descent of the elevating bucket, push-button control being provided both at the top of the pocket and in the hoist house for the stopping and starting of the motor. (*Railway Age*, vol. 74, no. 29, June 23, 1923, pp. 1533–1534, 4 figs., *d*)

Power and Process Steam in a Cotton-Goods Finishing Plant, Alfred Iddles. Description of an installation in a cotton-goods bleaching, dyeing, printing, and finishing plant which includes a combination of non-condensing and bleeder-type turbines.

The finishing of cotton goods requires a large amount of power and heat. In New England the power can frequently be obtained from the rivers, but heat has to be generated by fuel. The power load does not parallel the needs for heat, so that there is frequently much waste of heat. The variation in heat requirements due to changing process needs and seasonal heating demands and the fluctuation in power obtainable from the rivers make it necessary to have a very flexible power- and heat-generating plant if the maximum economy is desired.

The present article describes the way in which this problem was met in the Norwich, Conn., plant of the U. S. Finishing Co. Careful analysis of operating conditions had shown that a combination consisting of two non-condensing turbines and one bleeder-type turbine could be operated with sufficient flexibility to care for the variable electrical load and at the same time produce no more than sufficient exhaust steam for the requirements of the mill. By the addition of an extra governor valve and proper arrangement of the turbine, it was found that the bleeder type could be converted into a bleeder and mixed-pressure type. Such a combination was desirable in order that the sudden fluctuation between the electrical load and the exhaust-steam requirements could be taken care of automatically.

The installation as finally chosen consists of

1 Two 750-kw. non-condensing geared turbo-generator sets operating between 175 lb. and 15 lb. gage pressure.

2 One 750-kw. bleeder mixed-pressure geared turbo-generator operating with 175 lb. pressure at the throttle, bleeding at 15 lb. pressure, and the exhaust from the last stages going to a surface condenser at 28 in. of vacuum.

A drawing in the original article shows the piping system which was installed for distribution of live steam to the turbines and to the mill for processes which require pressures higher than 15 lb.

An interesting feature of this plant is the installation of steam flow meters in an effort to account for all the steam produced. There are both recording instruments which are located in the power plant and on the gage board, and integrating and recording meters located in the master mechanic's office in the mill.

The original article describes in detail the various features of the installation including the operation of turbine units. (*Textile World*, vol. 64, no. 1, July 7, 1923, pp. 83–91, 13 figs., *dA*)

RAILROAD ENGINEERING

Conical-Bottom Tanks in Water-Softening Plants

New Features in Water-Softening Plants, C. R. Knowles. Description of a type of water-softening plant adopted by the Illinois Central for twelve units to be used between Clinton, Ill., and Omaha, Neb. These plants are all of the continuous type and represent a new design in the construction of the tanks and housings.

The treating-plant houses are of a uniform design and are built in two sizes, 20 ft. by 40 ft. and 20 ft. by 60 ft., depending upon the capacity of the plant and the amount of storage space required. A space of 20 ft. by 20 ft. is reserved for the chemical equipment, filters, etc., and the remainder is used for storage of chemicals, the smaller house having storage space for two cars of chemicals and the larger house for four cars. That portion of the house reserved for the equipment has a 12-ft. ceiling to allow the necessary headroom for tanks, shafting, etc., while the storage room has a 10-ft. ceiling, as it is impractical to pile the chemicals in storage higher than 8 ft.

This type of structure increases the cost of the building slightly but adds materially to its appearance and convenience and is a pleasing departure from the barnlike appearance of many of the treating-plant houses formerly constructed.

The outstanding feature of these new plants is the conical-bottom tank which is a radical departure from the commonly accepted practice of building flat-bottom steel tanks of the standpipe type resting upon a concrete ring filled with broken stone or elevated wood tanks of similar design. A great deal of attention was given to the tank in designing these softening plants, and the conclusions reached, which have been borne out in practice, may be of interest.

Some authorities on water softening maintain that the movement of the water after leaving the downcomer is at an angle of 40 to 60 deg. upward and outward toward the walls of the tank, and that the water in the angle formed by the bottom and walls of the tank may be classified as dead water and should not be considered in figuring the available reaction time. This is undoubtedly true to a great extent, depending, of course, upon the relative temperatures of the incoming water and of the water of the tank. If the temperature of the incoming water is higher than that of the water in the tank, the movement as it leaves the downcomer will naturally be upward and as the temperature is equalized by contact with the water in the tank, it will probably spread toward the outside of the tank at an angle from the downcomer. On the other

hand, if the temperature of the incoming water is lower than that of the water within the tank, the movement will be along the bottom of the tank and the dead water will be displaced until the temperature of the water is equalized. This is of first importance in the selection of the type of tank to be used in the treatment of well waters.

The principal advantage of the conical-bottom tank in water softening is found to be in the collection and removal of the sludge and the resultant saving in water used for sludging over the flat-bottom tank. This feature alone will pay a good return on the cost of the tank. In the flat-bottom tank the sludge is distributed over the entire bottom of the tank and its removal necessitates the construction of an expensive sludge-collecting system, usually consisting of pipe with openings placed at intervals over the bottom of the tank, the most efficient of which are so arranged that the system may be operated in sections with from two to four sludge valves for each tank. Another type of sludge system is so constructed that the collecting pipes may be rotated over the bottom of the tank. None of these systems has been found entirely satisfactory, however, as they will not completely remove the sludge and are wasteful of water, as the sludge nearest the outlet is the first to be picked up and from two-thirds to three-fourths of the openings are discharging clear water long before the sludge near the outer edge of the tank is disturbed.

The sludge falls to the bottom of the conical-bottom tank and accumulates in the mud drum or riser where it is easily removed through a single opening and with a minimum waste of water. Actual tests to determine the amount of water in removing sludge show that the flat-bottom tank requires from four to eight times more water than a conical-bottom tank, depending on the efficiency of the sludge system and the amount of sludge deposited.

Tests were carried out to determine the amount of water required to remove the sludge from tanks. In the case of a flat-bottom tank 22 ft. in diameter, after 12 hr. operation, during which time 120,000 gal. of water had been treated, the sludge amounted to approximately 520 lb. About 5000 gal. of water was used to remove it, and even after that the tank was not clean by any means. When the tank was drained it was found that sludge had accumulated to a depth of 3 ft. all around the edge of the tank and there was a great deal of sludge between the sludge lines.

A similar test was made with a conical-bottom treating tank 28 ft. in diameter. After 60 hr. operation, during which time 1,000,000 gal. of water had been treated and the sludge deposit amounted to over 4000 lb., it was found that 2300 gal. of water was sufficient to remove the sludge completely. Other advantages of the conical-bottom tank, such as rate of upflow, are discussed in the original article. (*Railway Engineering and Maintenance*, vol. 19, no. 7, July 1923, pp. 273–276, 5 figs., *d*)

REFRIGERATION

Specific Volume of Saturated Ammonia Vapor, C. S. Cragoe, E. C. McKelvy, and G. F. O'Connor. The specific volume of saturated ammonia vapor was measured in the temperature interval —50 to +50 deg. cent. by two methods, one involving a direct determination of the mass of the vapor contained in a known volume, and the other an optical method, involving measurements of the index of refraction of the vapor.

Three picnometers of different total volumes were used in the measurements by the direct method. The effect of adsorption was studied and found to be of a magnitude comparable with the limit of accuracy of that method.

Two methods of measurement were used, and the possible sources of error in the two methods are discussed. The final results are represented closely by the empirical equation:

$$\log_{10} u' = 300\left[\frac{6.46344}{\theta} - 0.106887 + 0.0356803 \log_{10}\theta\right] + 0.0862366\sqrt{406.1-\theta} + 0.002667\ (406.1-\theta)$$

in which u' is expressed in cubic centimeters per gram and θ in degrees absolute (deg. abs. = deg. cent. + 273.1). (*Scientific Paper of the Bureau of Standards*, no. 467, Mar. 17, 1923, pp. 707–735, 4 figs., *e*)

VARIA

American Continent Hydroelectric Power Scheme

Data concerning a novel power scheme to cover the entire continent of North America, that is, not only the United States proper, but also Alaska and Canada.

The new scheme is based on what is called the diversity factor of the main river systems of the North American continent, together with the oscillating power demand over the entire continent due to differences in time. If one looks at North America as one vast hydraulic engine, it may be conceived as throbbing with power throughout the year. It is not only the regular water-levels that oscillate. The flood crests too are spaced out over the year, and form headwaters to sea level. As the floods move down the rivers past successive power plants they lengthen the period of maximum power in their water sheds. The lakes, including the Great Lakes, are likewise variable in volume and level in a cycle running almost seven years from low to high and the excess water of the peak years can be impounded and used as a booster for a continental power system.

In addition to the storage of water from the lake system, storage works may be built to realize the utmost constant power from streams with high head of water. On the bulk of the low-head streams, however, power-plant construction will take the form of "over development," that is, the construction of power plants in series from headwaters to mouth to develop the flood power of the stream as it comes down.

It is claimed that a smaller total of storage will be required to produce the same amount of constant power from a continental system than would be needed for plants developed apart. The extent to which the Great Lakes alone could be used as reservoirs of power to boost a continental system through a seasonal or cyclical low-water period seems almost without limit. Storage of one extra foot of water in the Michigan-Huron system would make available power in enormous quantitise.

The problem of the transmission of power in a manner that would make the continental system possible is not considered by the authors of the article as excessively difficult of solution. Two hundred and twenty thousand volt power lines are already in commercial operation. To make the water power of the Sierras available to the prairie states lines up to 350,000 volts may be required and the Tribune's investigations point to the necessity of using still higher voltages, figures of 1,000,000 and 2,000,000 volts being mentioned as within the bounds of possibility within comparatively short time.

It is claimed that a continental system will develop far more primary power than America will need for generations, but there are forces now in evidence in agriculture, transportation and industry which will make it increasingly possible to coördinate industrial effort to periods when the greatest volume of power is available. It seems highly probable to the Tribune investigators that in the streams of Canada and Alaska may lie the solution of the whole low-water problem. These rivers head in snow and ice and come to full flood as the southern streams are receding. From their connection with lake systems it seems probable that the application of storage methods will make it possible to impound the flood from melting snow and ice for regulated discharge over the period in which the streams of the south reach their low level.

The minimum potential water power of the United States based on the average periods of lowest flow in each year is estimated to be about twenty-eight million horsepower. This does not include the smaller streams and leaves out Canada. The horsepower capable of development under a continental system is estimated to amount to two hundred and eighty million horsepower. This is approximately more than twice the power of all kinds now installed in the United States and most of this installed power is employed for only brief periods of time. (*Chicago Sunday Tribune*, Aug. 5, 1923, *g*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general, *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Test Code for Stationary Steam-Generating Units

Preliminary Draft of Another Code in the Series of Nineteen Being Formulated by the A.S.M.E. Committee on Power Test Codes

In 1918 the Committee on Power Test Codes was reorganized by the Council of The American Society of Mechanical Engineers to revise and enlarge the Power Test Codes of the Society published in 1915. The committee consists of a main committee of twenty-five members under the chairmanship of Fred R. Low, and nineteen individual committees of specialists who are drafting test codes for the various prime movers and the other apparatus which comprise power-plant equipment.

The individual committee which developed the Test Code for Stationary Steam-Generating Units is headed by Edwards R. Fish as Chairman, the other members being Arthur D. Pratt, Alex. D. Bailey, Albert A. Cary, and Edwin B. Ricketts. William N. Best, now deceased, was also a member of this committee.

The committee and the Society will welcome suggestions for corrections or additions to this draft of its code from those who are specially interested in the manufacture and use of stationary steam generating units. These comments should be addressed to the Chairman of the Committee in care of The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y.

Introduction

1 The Test Code for Stationary Steam-Generating Units applies to the boiler, fuel-burning apparatus of whatsoever nature, superheaters, and economizers, but not to apparatus required for their operation such as engines or motors for driving stokers, feed pumps, etc. Economizers are considered as part of the generating units, and the form of test report provides for their inclusion in an overall test. They may be divided into two general classes, (*a*) separate economizers, being those with their own housing and connected to the boilers with flues, and (*b*) integral economizers, which are contained within the boiler setting and through which a part of the boiler circulating water may or may not pass.

Observations when testing steam-generating units equipped with the first-named class may readily be separated so as to either include or exclude the economizer in the results. In the case of the second class, however, it is practically impossible to segregate the economizer from the boiler, and tests of units so equipped should be conducted and reported as if the economizer was a part of the boiler proper, full notes being made to that effect.

2 Boiler testing should not be lightly undertaken by any one who has not had some training under an experienced testing engineer if reliable results are to be expected. The whole matter should be thoroughly understood, both theoretically and practically. Accurate tests depend very largely upon the care and faithfulness of the observers. It is much easier to make mistakes than is realized by those who are not familiar with practical testing.

The absolute accuracy of the results of a boiler test, even when conducted with the greatest care, is doubtful, but there is as yet no possible basis upon which to determine what the probable limits of error might be. It is generally conceded, however, that there are several sources of indeterminate error, the more important of which are discussed below. The limits of accuracy of a test may very reasonably be taken to be within plus or minus 3 per cent.

One of the sources of probable error is the sampling of coal. Even when the greatest care is taken to obtain a representative sample, there may be an indeterminate error in ascertaining the heating value of the coal, even though the laboratory analysis is most reliable. With modern apparatus these laboratory determinations should be substantially correct as regards the sample tested; but the question as to how truly the same represents the whole is always present and cannot be answered indubitably.

Another source of error is the moisture contained in the coal. As explained in the preceding paragraph, the sampling is more or less uncertain. It is contended by some that if the attempt is made to determine the moisture during the test, the methods of drying and weighing are unreliable; while others contend that though the moisture as determined in the laboratory is accurate so far as the sample delivered to the laboratory is concerned, this sample probably does not represent the bulk of the coal actually burned, since there must inevitably have been more or less loss of moisture during the collection, preparation, and handling of the sample.

Similarly, it is problematical whether the samples collected for the determination of the moisture in steam and for gas analysis are representative of the bulk, although the testing of the samples obtained may be quite accurate.

It is not unusual for heat balances to be reported to the nearest B.t.u. and to the nearest one-tenth of 1 per cent. But the present state of the art of boiler testing does not provide means for attaining anything like this accuracy. In general, results should be reported only to the nearest significant figure. Reporting results of any kind in small units is likely to convey an erroneous idea as to the real accuracy of the figures.

It is therefore quite logical in the case of guarantee tests that a substantial compliance with the guarantee be accepted as full compliance therewith. A limit of tolerance should be agreed upon beforehand by the parties to the test. The amount of this tolerance might well bear some relation to the care exercised in arranging the details and in the conducting of the test.

Object and Preparations

3 Definitely determine the object of the test and keep it continuously in mind. Take the dimensions, note the physical conditions, examine for leakage, install the testing appliances, etc., as pointed out in the "General Instructions," Pars. 1 to 4, and make preparations for the test accordingly.

4 Determine the character of the fuel to be used.

5 In guarantee tests with fuel of a specified heating value or other characteristics, there should be a clear understanding as to the permissible variation from the specified characteristics.

In guarantee tests of a waste-heat boiler, the performance of which is dependent upon gas weight and entering gas temperature, there should be a clear understanding as to the method to be used in the determination of the gas weight and the measurement of the gas temperature.

6 If the size of coal is to be reported, it should be determined in accordance with Pars. — to — of the Test Code on Fuels.

Instruments and Apparatus

7 The instruments and apparatus required for boiler tests are:

(*a*) Scales for weighing coal, oil, or other fuel, ashes, furnace refuse, etc.
(*b*) Graduated scales attached to the water glasses
(*c*) Tanks or tanks and scales for volumetric or weight measurement of water
(*d*) Meters or other apparatus for measuring gaseous fuels
(*e*) Pressure gages, thermometers, pyrometers and draft gages
(*f*) Calorimeter for determining the quality of the steam
(*g*) Gas-sampling and analyziug apparatus.

8 Full directions regarding the design, use, and calibration of the above-mentioned appliances are given in the Code on Instruments and Apparatus, Pars.—to—.

9 As no two plants are alike, it is quite impracticable to do more than suggest how and where the various instruments should be located.

9a Fuel-weighing apparatus should be near the point where the fuel is to be used, under direct observation of and convenient to the one in charge of the test. The weighing of refuse may be done at any convenient point.

9b The water-glass scale should be so attached that the breaking of the glass will not disturb the scale.

9c The water-weighing or measuring apparatus if other than a meter should be arranged in an easily accessible place and made as convenient as practicable. It should also be under the direct observation of the one in charge of the test.

9d Meters or other apparatus for measuring gaseous fuel may be placed in such locations as conditions dictate.

9e Pressure gages should be away from any disturbing influences, such as extreme heat, and in a position to be easily read. Thermometers for determining atmospheric temperatures should be placed so as to give an average indication away from cold or hot drafts, etc.

A thermometer well for measuring feedwater temperatures should be as close to the boiler inlet as possible and the pipe between boiler and thermometer should be well protected with heat-insulating covering.

Saturated-steam temperatures may be measured at any point in the steam pipe where the pressure is the same as that where the temperature is desired, care being taken that the well is not cooled by the condensate. The temperature and pressure of superheated steam should be measured as close to the outlet of the superheater as possible, eliminating all losses by pressure drop and radiation between the superheater and thermometer.

Pyrometers of any type must have the part on which the heat impinges so located that the temperature which it is desired to measure is actually obtained. Much experience and good judgment are essential in order to obtain even approximately reliable readings.

Draft at the gas outlet is usually measured if nowhere else. It is often desirable to know the draft at other points of the setting, in which cases the several locations should be chosen to suit the information wanted. Care should be exercised to see that the ends of the connecting pipes are not obstructed and that the open ends are not subject to other than static pressures. All joints of draft-gage connections must be tight.

9f The sampling tube of the calorimeter should be as close to the point at which the quality of steam is desired as possible. All exposed piping in which condensation might influence the result must be well lagged. Ordinarily the quality of the steam leaving the boiler, or that entering the superheater, is desired.

9g Analysis of the exit gases is usually what is taken, but very frequently analyses are wanted from other points. Sample tubes must be so located that only the gas to be analyzed enters the tube and precautions taken against the possibility of inleakage of air anywhere in the line. The gas-analyzing apparatus should be in a readily accessible and protected place with good light and convenient facilities. See Code on Instruments and Apparatus, Pars.—to—.

Operating Conditions

10 Determine what the operating conditions and method of firing should be to conform with the object in view, and see that they prevail as nearly as possible throughout the trial.

11 The duration of tests to determine the efficiency of a steam-generating unit burning coal either hand or stoker fired should preferably be 24 hours, but where operating conditions do not permit or other considerations make it advisable or necessary the length of test may be reduced to not less than 10 hours. When the rate of combustion is less than 25 lb. of coal per sq. ft. of grate surface per hour the test should be continued until a total of 250 lb. per sq. ft. of grate area has been burned, except that in cases where a type of stoker is used that does not permit the quantity of fuel and (or) the condition of the fuel bed to be accurately estimated the duration of test should not be reduced below that required to minimize the error.

12 In the case of a unit using pulverized fuel the duration of test should be not less than 6 hours, and for liquid or gaseous fuel not less than 4 hours.

13 In the case of a waste-heat unit, where the operation of the industrial furnace is continous and furnace conditions are constant, the duration of the test should be not less than 6 hours. Where the industrial-furnace operation is in cycles, the test should be of such duration as to cover at least one cycle of furnace operation.

14 In tests conducted under plant-operation conditions where the service requires continuous operation night and day, with frequent shifts of firemen, the duration of test should be at least 24 hours. Likewise in such tests, either of a single boiler or of a plant of several boilers which operate regularly a certain number of hours and during the remainder of the day are banked, the duration should be not less than 24 hours.

15 The duration of tests to determine the maximum evaporative capacity of a steam-generating installation, when the efficiency is not determined, should be not less than 2 hours, unless otherwise agreed upon.

Starting and Stopping

16 Combustion, fuel, draft, and temperature conditions, the water level, rate of feeding water, rate of steaming, and the steam pressure should be as nearly as possible the same at the end as at the beginning of the test. If an economizer is included in the unit tested the average temperature of the water within it should be the same at the start and end of test.

17 To secure the desired equality of conditions with hand-fired boilers, the following method should be employed:

The furnace being well heated by a preliminary run at the same combustion rate that will prevail during the test and sufficiently long to thoroughly heat the setting, burn the fire low and thoroughly clean it, leaving enough live coal spread evenly over the grate (say, from 2 to 4 in.) to serve as a foundation for the new fire. Note quickly the thickness of the coal bed as nearly as it can be estimated or measured, also the water level, the steam pressure, and the time, and record the latter as the starting time. Fresh coal should then be fired from that weighed for the test, the ashpit thoroughly cleaned, and the regular work of the test proceeded with.

Before the end of the test the fire should again be burned low and cleaned in such a manner as to leave the same amount of live coal on the grate as at the start. When this condition is reached, observe quickly the water level, the steam pressure, and the time, and record the latter as the stopping time. If the water level is lower or higher than at the beginning, a correction should be made by computation, not by feeding additional water. Finally remove the ashes and refuse from the ashpit.

In a plant containing several boilers, where it is not practicable to clean them simultaneously, the fires should be cleaned one after the other as rapidly as may be, and each one after cleaning charged with enough coal to maintain a thin fire in good working condition.

After the last fire is cleaned and in working condition, burn all the fires low (say, 4 to 6 in.), note quickly the thickness of each, also the water levels, steam pressure, and time, which last is taken as the starting time. Likewise, when the time arrives for closing the test the fires should be quickly cleaned one by one, and when this work is completed they should all be burned low the same as at the start, and the various final observations made as before stated.

In the case of a large boiler having several furnace doors requiring the fire to be cleaned in sections one after the other, the above directions pertaining to starting and stopping in a plant of several boilers may be followed.

18 To obtain the desired equality of conditions when a mechanical stoker is used, the above procedure should be modified as follows:

Stokers should be in operation at approximately the same rate that will prevail during the test for at least 12 hours before starting test. At the start and finish of the test, level the coal in stoker hopper. Make starting and stopping observations as in hand fired tests.

18a *Stokers of the Continuous-Dumping Type.* The desired operating conditions, i.e. speed and stroke of coal-feeding mechanism, speed of grate, intensity of draft or blast, and rate of water feed should be maintained as nearly constant as possible for at least one hour, and preferably for two hours, before starting and stopping the test.

18b *Stokers of the Intermittent-Dumping Type.* Proceed as above, except that stokers should be cleaned about one hour before starting and before stopping the test.

19 To obtain the desired equality of conditions when pulverized, liquid, or gaseous fuel is used, the following method should be employed:

The boiler or boilers to be tested should be operated before the start of the test under the fuel, furnace, and combustion conditions which are to be maintained throughout the test for a period of not less than three hours. Fuel temperature, fuel pressure and draft conditions should be kept as nearly constant as possible during this period and throughout the test. The references above for hand-fired tests as to starting and stopping observations hold also for pulverized-, liquid-, and gaseous-fuel tests.

20 In the case of a waste-heat boiler set in connection with an industrial furnace the operation of which is continuous, the rules governing the starting and stopping of tests with pulverized, liquid, or gaseous fuels will apply. Where the industrial furnace operates in cycles, the start and end of the test should be at the same point of two or more successive cycles. Starting and stopping observations should be in accordance with the previous rules.

Records

21 The records of data should be obtained as pointed out in Tables 1*a* to 12*b*. Readings of the instruments at 15-minute intervals are usually sufficient. If there are sudden and wide fluctuations, the readings should be taken at 10-minute intervals, or at such frequency as may be necessary to determine the true nature of the variation.

22 The approximate quantity of fuel needed each hour should be determined, and if the quantity required and inconvenience due to lack of room is not too great, the whole amount should be delivered on the firing floor at the beginning of each hour. If any is left at the end of the hour the quantity should be estimated. In this way the amount of fuel used per hour can be determined and the approximate results be followed from hour to hour.

If the whole amount cannot be delivered at the beginning of the hour, convenient quantities may be weighed out at appropriate intervals so as to come out about even at the end of the hour. When hopper scales are used, receiving coal from bunkers and discharging directly into furnace hoppers, hourly quantities may be roughly determined by estimating furnace conditions. These

hourly quantities should be properly noted on the log sheet. They are taken as a matter of convenience and guide, but only the totals are to be used in the final calculation.

23 The records should be such as to ascertain also the approximate consumption of feedwater each hour, and thereby determine the degree of uniformity of evaporation. The maintenance of a uniformity of evaporation is greatly facilitated by the use of some form of graphic recording steam meter, which should be so placed as to keep continuously before the operator the rate of evaporation. Since the indications of this meter are not used in any of the test calculations, extreme accuracy is not essential.

24 *Quality of Steam.* If the boiler does not produce superheated steam, the quality of the steam should be determined by the use of a throttling or separating calorimeter in the manner pointed out in the Code on Instruments and Apparatus, Pars. — to —. If the boiler has superheating surface, the temperature of the steam should be determined by the use of a thermometer inserted in a thermometer well, as pointed out in Par. — of the above-mentioned code.

25 *Sampling Fuel.* During the progress of the test fuel should be regularly sampled for purposes of analysis, as pointed out in the Test Code on Fuels, Pars. — to —.

26 *Ashes and Refuse.* The ashes and refuse withdrawn from the furnace and ashpit during the progress of and at the end of the test should be weighed, as far as possible, in a dry state. If wet, the amount of moisture should be ascertained and allowed for, a sample being taken and dried for this purpose. This sample may also serve for analysis.

Ash sampling is at best subject to large errors, and every precaution should be taken to insure as representative a sample as possible. If sufficiently hot to allow combustion to proceed, ash should be thoroughly quenched with water immediately after dumping into the ashpit. Enough time should elapse before weighing to permit the heat of the refuse to drive out most of this moisture. If possible, all the ash should then be passed through a crusher, thoroughly mixed, and reduced to a laboratory-size sample by successive quartering. If it is impracticable to crush all the ash, the clinkers and fines should be placed in separate piles, and each pile weighed and sampled separately, the two samples being combined in proportion to the relative weights of their respective piles.

27 *Calorific Tests and Analyses of Fuels.* The quality of the fuel and of the furnace ash and refuse should be determined by calorific tests and analyses of the fuel sample above referred to. Directions for obtaining samples and making these tests and analyses will be found in the Test Code on Fuels under the headings "Fuel Calorimeters" and "Fuel-Analysis Apparatus," Pars. — to —.

28 *Analyses of Flue Gases.* For approximate determinations of the composition of the flue gases, the Orsat apparatus or some modification thereof should be employed. Gas samples should preferably be taken continuously, but if momentary samples are obtained the analyses should be made as frequently as possible, noting the furnace and firing conditions at the times the sample are drawn. Where the firing is intermittent, gas samples should be taken at such intervals that the complete firing cycle will be covered by the average of individual readings. If the sample drawn is a continuous one the intervals may be made longer. Where the unit includes an economizer, gas analyses should be made at both boiler and economizer outlet.

Fuller directions will be found in the Code on Instruments and Apparatus, under the heading "Gas-Analysis Apparatus," Pars. — to —.

29 *Smoke Observations.* In tests requiring a determination of the amount of smoke produced, observations should be made regularly throughout the trial at intervals of five minutes, or if necessary, of one minute. For observations covering a period of one or more single firings with solid fuel, the intervals should be one-quarter minute or less.

30 *Appliances and Methods Pertaining to Smoke Determination.* No wholly satisfactory methods for either quantitative or qualitative smoke determinations have yet come into use, nor have any reliable methods been established for definitely fixing even the relative density of the smoke issuing from chimneys at different times. One method commonly employed, which answers the purpose fairly well, is that of making frequent visual observations of the chimney at intervals of one minute or less for a period of one hour and recording the observed characteristics according to the degree of blackness and density, and giving to the various degrees of smoke an arbitrary percentage value rated in some such manner as the following:

Smoke Percentages

Dense black	100	Light gray	20
Medium black	80	Very light	5
Dense gray	60	Trace	1
Medium gray	40	Clear chimney	0

The color and density of smoke depend somewhat on the character of the sky or other background, and on the air and weather conditions obtaining when the observation is made, and these should be given due consideration in making comparisons. Observations of this kind are also subject to personal errors and errors of judgment. Nevertheless these methods are useful especially when the results are plotted, according to the percentage scale determined on, so that a graphic representation of the changes can be shown. The observations should be considered as only roughly indicating the smoke conditions and are comparable only when made by the same observer.

Various forms of charts and clouded-glass arrangements for comparing and fixing smoke densities have been proposed, and to some extent used, but these have proved more or less unsatisfactory and they are subject to personal errors, and to sky, wind, and weather conditions, the same as the simpler method above described.

Among the chart methods referred to, the use of the Ringelmann smoke chart is perhaps the most familiar.

Another method of smoke determination consists in the use of a narrow, flat metal plate suspended in the flue, the character of the smoke being indicated by the amount and quality of the soot and dust deposited upon the plate in a given time. This method, like others, is useful in furnishing a means of comparison in different cases rather than a means of exact determination.

Among the latest methods brought out for indicating and recording the density of smoke is one depending on the variations in the electrical conductivity of the metal selenium due to variations in the intensity of light shining upon it. Openings are provided on either side of the flue directly opposite each other. The selenium is located at one opening and a strong light at the other. The intensity of the light rays falling on the selenium varies with the density of the smoke. A milliampere meter in circuit with the selenium cell registers the variations.

Ringlemann Smoke Chart. A Ringlemann smoke chart is shown with full-size spacing in Fig. 1. To use this chart, four cards are ruled like those shown, though covering a much larger area, and placed in a horizontal row about 50 ft. from the observer, and in line between him and the chimney, together with two other cards, one of which is white and the other solid black. The observer glances rapidly from the chimney to the cards and judges which one corresponds with the color and density of the smoke. He makes these observations every minute, or oftener if desired, recording the number of the card representing the character of the smoke at the instant of observation. The results are then plotted on a chart, and the variations shown graphically.

The lines in cards 1 to 4 are respectively 1, 2.3, 3.7, and 5.5 mm. thick, and the spaces 9, 7.7, 6.3, and 4.5 mm. The lines should be made with black india ink.

Fig. 1 Ringlemann Sample Chart

31 *Chart.* In trials having for an object the determination and exposition of the complete boiler performance, the entire log of readings and data should be represented graphically. See Appendix A.

Calculation of Results

32 The test report should state the source of numerical constants or other values used in the computations.

33 It is recommended that a record be kept of the energy used by auxiliaries immediately connected with the steam generating unit being tested and a specific note made thereof; no deductions, however, shall be made on the report forms or in computing results unless the object of the test so requires, in which case the report should specifically so state. This applies to steam or power used in driving stokers or other fuel-feeding apparatus, oil burners, fans, feed pumps, soot blowers, etc.

Data and Results

34 The data and results should be reported in accordance with the tables given herewith, using the proper table for the class of fuel burned. If necessary, items of data not provided for may be added, or if certain items are not required such may be omitted, as may conform to the object of the test. Unless otherwise indicated, the quantities should be the average of the observations.

APPENDIX A

Chart of Observed Data

APPENDIX B

Isocalorific and Isovolatile Curves

Table 1a Data and Results, Test of Stationary Steam-Generating Unit. Solid Fuels—As Fired—Dry

General Information

(1) Date of test
(2) Location of plant
(3) Owner of plant
(4) Maker and type of boiler
(5) Maker and type of superheater
(6) Maker and type of economizer
(7) Maker and type of air heater
(8) Maker and type of fuel-burning equipment
(9) Test conducted by
(10) Object of test

Description, Dimensions, Etc.

(11) Boiler heating surface .... sq. ft.
(12) Superheater surface .... sq. ft.
(13) Economizer surface .... sq. ft.
(14) Air heater surface .... sq. ft.
(15) Grate surface .... sq. ft.
(16) Fuel burning equipment
(17) Draft
(18) Fuel
(19) Volume of combustion space .... cu. ft.
(20) Furnace, center of grate to nearest heating surface .... ft.
(21) Furnace volume per sq. ft. boiler heating surface .... cu. ft.

Fuel and Gas Analyses and Data

Fuel Proximate Analysis—Dry—As Fired

(22) Volatile matter .... per cent
(23) Fixed carbon .... per cent
(24) Ash .... per cent
(25) Moisture (as fired) .... per cent
(26) B.t.u. per lb. (as fired)
(27) B.t.u. per lb. (dry)
(28) Fusion temperature of ash .... deg. fahr.
(29) Size of coal as fired

Fuel Ultimate Analysis

(30) Carbon .... per cent
(31) Hydrogen .... per cent
(32) Oxygen .... per cent
(33) Nitrogen .... per cent
(34) Sulphur .... per cent
(35) Ash .... per cent

Gas

(36) Gas analysis, furnace:
Per cent CO_2......O_2......CO......N_2......SO_2......
(37) Gas analysis, boiler outlet:
Per cent CO_2......O_2......CO......N_2......SO_2......
(38) Gas analysis, economizer:
Per cent CO_2......O_2......CO......N_2......SO_2......
(39) Gas analysis, air heater:
Per cent CO_2......O_2......CO......N_2......SO_2......
(40) Dry gas per lb. fuel, furnace (as fired, dry) .... lb.
(41) Dry gas per lb. fuel, boiler outlet (as fired, dry) .... lb.
(42) Dry gas per lb. fuel, economizer (as fired, dry) .... lb.
(43) Dry gas per lb. fuel, air heater (as fired, dry) .... lb.
(44) Dry gas per lb. fuel, theoretical (as fired, dry) .... lb.
(45) Air supplied per lb. fuel, furnace (as fired, dry) .... lb.

Pressures and Drafts

(46) Moisture in air .... lb. per lb. air
(47) Steam pressure by gage, boiler .... lb. per sq. in.
(48) Steam pressure by gage, superheater outlet .... lb. per sq. in.
(49) Air pressure in ashpit zone, at burners .... in. of water
(50) Draft in furnace .... in. of water
(51) Draft at boiler outlet .... in. of water
(52) Draft at economizer outlet .... in. of water
(53) Draft at air-heater outlet .... in. of water

Temperatures

(54) Steam temperature .... deg. fahr.
(55) Moisture in steam .... per cent
(56) Superheat .... deg. fahr.
(57) Temperature of air surrounding boiler, T_1 .... deg. fahr.
(58) Temperature of air entering air heater, T_2 .... deg. fahr.
(59) Temperature of air leaving air heater, T_3 .... deg. fahr.
(60) Temperature of air for combustion, T_4 .... deg. fahr.
(61) Temperature of air furnace, T_5 .... deg. fahr.
(62) Temperature of gases leaving boiler, T_6 .... deg. fahr.
(63) Temperature of gases leaving economizer, T_7 .... deg. fahr.
(64) Temperature of gases leaving air heater, T_8 .... deg. fahr.
(65) Temperature of feedwater entering boiler, T_9 .... deg. fahr.
(66) Temperature of feedwater entering economizer, T_{10} .... deg. fahr.
(67) Temperature of water in boiler at point where gases leave boiler, T_{11} .... deg. fahr.
(68) Temperature of fuel, T_{12} .... deg. fahr.

Hourly Quantities

(69) Duration of test .... hr.
(70) Fuel as fired per hour .... lb.
(71) Dry fuel per hour .... lb.
(72) Fuel as fired per sq. ft. of grate per hour .... lb.
(73) Fuel as fired per sq. ft. of retort or per burner per hour .... lb.
(74) Dry fuel per sq. ft. of grate per hour .... lb.
(75) Dry fuel per retort or per burner per hour .... lb.
(76) Combustion space per lb. coal per hour (as fired, dry) .... cu. ft.
(77) Refuse per hour .... lb.
(78) Actual water per hour .... lb.
(79) Factor of evaporation .... lb.
(80) Equivalent evaporation per hour .... lb.
(80a) Boiler horsepower, average .... hp.

Refuse

(81) Refuse, per cent of fuel (as fired, dry) .... per cent
(82) Percentage of combustible in refuse .... per cent
(83) Carbon burned per lb. fuel (as fired, dry) .... lb.

Evaporation

(84) Actual evaporation per lb. fuel (as fired, dry) .... lb.
(85) Equivalent evaporation per lb. fuel (as fired, dry) .... lb.
(86) Equivalent evaporation per lb. dry fuel .... lb.
(87) Equivalent evaporation per sq. ft. heating surface per hr .... lb.
(88) Number of 1000 B.t.u. absorbed per sq. ft. of boiler heating surface per hour .... B.t.u.
(89) Percentage rating .... per cent

Efficiency

(90) Efficiency of boiler, superheater, furnace, grate, and air heater .... per cent
(91) Efficiency including economizer .... per cent

Table 1b Heat Balance of Steam-Generating Unit, Short Form. Solid Fuels

Item	B.t.u.	Per cent
(92) = Heat absorbed by water and steam in boiler and superheater	....	....
(93) = Heat absorbed by water in economizer	....	....
(94) = Heat loss due to moisture in coal	....	....
(95) = Heat loss due to water from combustion of hydrogen	....	....
(96) = Heat loss due to moisture in air	....	....
(97) = Heat loss due to dry chimney gases	....	....
(98) = Heat loss due to incomplete combustion of carbon	....	....
(99) = Heat loss due to unconsumed combustible in refuse	....	....
(100) = Heat loss due to unconsumed hydrogen and hydrocarbons	....	....
(101) = Heat loss due to radiation and unaccounted for	....	....

Table 1c Computations for Test of Stationary Steam-Generating Unit. Solid Fuel

Explanation of Symbols

Wherever CO_2, O_2, CO and N_2 are used they are the percentages by volume of these constituents in the gases of combustion.

H = total heat (in B.t.u. per lb.) of saturated steam at the boiler outlet pressure.
H_1 = total heat (in B.t.u. per lb.) of superheated steam at the superheater outlet pressure.
h = total heat (in B.t.u. per lb.) in feedwater at boiler inlet.
h_1 = total heat (in B.t.u. per lb.) in feedwater at economizer inlet.
L = latent heat (in B.t.u. per lb.) in steam at pressure in steam main.
t_2 = temperature of steam after expansion in calorimeter.
T_{13} = initial temperature of water for quenching ashes.
T_{14} = final temperature of water for quenching ashes.
W = weight of water used per hour for quenching ashes.

General

If test is on a dry basis, draw a line through "as fired" wherever the words "as fired, dry" appear together, and vice versa. Whichever basis is chosen must be followed throughout. Percentage results in heat balance will be the same in either case.

Item 11 to 14—Heating surface shall consist of that portion of the surface of the heat-transfer apparatus exposed to both the gases being cooled and the fluid being heated at the same time computed on the gas side.

Item 15—The projected area within the four walls surrounding the grate.

Item 17—State whether natural, forced, induced or a combination of one or more kinds of draft were employed.

Item 18—State general class of fuel, as anthracite, bituminous, wood refuse, etc. Also give district where produced.

Item 19 = The cubic space provided for the combustion of fuel before the products of combustion pass through any heating surface.

Items 22 to 35 = As fired analysis items = dry analysis items × $\left(1 - \frac{\textit{Item 25}}{100}\right)$

$$\textit{Items } 40 \text{ to } 43 = \frac{11\,CO_2 + 8\,O_2 + 7(CO + N_2)}{3(CO_2 + CO)} \times \textit{Item } 83.$$

Use data from *Items* 36 to 39.

$$\textit{Item } 44 = 12.52 \times \textit{Item } 83 + \frac{26.56 \times \textit{Item } 31 + 3.325 \times \textit{Item } 34 + \textit{Item } 33}{100}$$

$$\textit{Item } 45 = \textit{Item } 40 + \frac{9 \times \textit{Item } 31}{100} - \frac{100 - \textit{Item } 81}{100}$$

Item 46—For methods of determination see code on Instruments and Apparatus Par.—.

Item 55—Determine either from charts or the following formula:

$$100 \times \frac{H - 1150.4 - 0.47 \times (t_2 - 212)}{L}$$

Item 77 = combined weight of ashes and cinders produced during test divided by Item 69. In tests of large boilers where it is impracticable to determine the amount of refuse by weighing, Item 77 may be calculated as follows:

$$\textit{Item } 77 = \frac{\textit{Item } 24}{100 - \textit{Item } 82} \times \textit{Item } 70 \text{ (or 71)}$$

$$\textit{Item } 79 \quad \text{(For saturated or wet steam)} = \frac{H - \dfrac{L \times \textit{Item } 55}{100} - h}{970.4}$$

$$\text{(For superheated steam)} = \frac{H_1 - h}{970.4}$$

$\textit{Item } 80 = \textit{Item } 78 \times \textit{Item } 79.$

$$\textit{Item } 80a = \frac{\textit{Item } 80}{34.5}$$

$$\textit{Item } 81 = \frac{\textit{Item } 77}{\textit{Item } 70 \text{ (or 71)}}.$$

$$\textit{Item } 83 = \frac{\textit{Item } 30}{100} - \frac{\textit{Item } 81 \times \textit{Item } 82}{10{,}000}$$

$$\textit{Item } 84 = \frac{\textit{Item } 78}{\textit{Item } 70 \text{ (or 71)}}$$

$$\textit{Item } 85 = \frac{\textit{Item } 80}{\textit{Item } 70}$$

$$\textit{Item } 86 = \frac{\textit{Item } 80}{\textit{Item } 71}$$

$$\textit{Item } 87 = \frac{\textit{Item } 80}{\textit{Item } 11}$$

$$\textit{Item } 88 = \frac{\textit{Item } 80 \times 970.4}{\textit{Item } 11}$$

$$\textit{Item } 89 = \frac{\textit{Item } 88a \times 10}{\textit{Item } 11}$$

$$\textit{Item } 90 = \frac{\textit{Item } 85 \text{ (or 86)} \times 970.4}{\textit{Item } 26 \text{ (or 27)}}$$

$$\textit{Item } 91 = \frac{\textit{Item } 85 \text{ (or 86)} \times 970.4 + (h - h_1) \times \textit{Item } 84}{\textit{Item } 26 \text{ (or 27)}}$$

Table 1*d* Heat-Balance Computations, Short Form, Solid Fuels

Item

(92) $= \textit{Item } 85 \text{ (or 86)} \times 970.4$

(93) $= \textit{Item } 84 \times (h - h_1)$

(94) $= \dfrac{\textit{Item } 25}{100} \times (1090.7 + 0.455\, T_6 - T_{12})$

(95) $= \dfrac{\textit{Item } 31}{100} \times 9 \times (1090.7 + 0.455\, T_6 - T_{12})$

If economizer is installed without air heater, substitute T_7 for T_6; if air heater is installed substitute T_8 for T_6 in Items 94, 95, 96 and 97.

(96) $= \textit{Item } 45 \times \textit{Item } 46 \times 0.455\, (T_6 - T_4)$.

This loss is small and is frequently included in Item 100.

(97) $= \textit{Item } 41 \text{ (42 or 43)} \times 0.24\, (T_6 - T_1)$.

If boiler and superheater use Item 41, if economizer use Item 42, if air heater use Item 43.

(98) $= \dfrac{CO}{CO_2 + CO} \times \textit{Item } 83 \times 10160$

If boiler alone use analysis from Item 37, if economizer use Item 38, if air heater use Item 39.

(99) $= \dfrac{\textit{Item } 81 - \textit{Item } 24}{100} \times 14600$

(100) $= \textit{Item } 26 \text{ (or 27)} - (\text{Sum of } \textit{Items } 92 \text{ to } 99, \text{ inclusive})$.

Table 2*b* Heat Balance of Steam-Generating Unit Comprising Boiler and Superheater, with or without Integral Economizer. Solid Fuels

Item	Heat Values	B.t.u.	Per cent
(92)	= Heat per pound coal as fired (high heating value)	....	....
(93)	= Heat absorbed by water and steam in boiler and superheater	....	....
(94)	= Heat absorbed by steam in superheater	....	....
	Unavoidable Losses		
(95)	= Heat loss due to moisture in coal, moisture accompanying theoretical air and water from combustion of hydrogen, up to T_{11}	....	....
(96)	= Heat loss due to theoretical dry gases, T_4 to T_{11}	....	....
(97)	= Total unavoidable losses	....	....
	Other Losses		
(98)	= Heat loss due to combustible in refuse	....	....
(99)	= Heat loss due to sensible heat in refuse, cinders, and soot	....	....
(100)	= Heat loss due to unburned gaseous combustibles	....	....
(101)	= Heat loss due to excess air entering furnace and moisture accompanying same, T_4 to T_{11}	....	....
(102)	= Heat loss due to theoretical dry gases, moisture in coal, moisture accompanying theoretical air, and moisture from combustion of hydrogen, T_{11} to T_6	....	....
(103)	= Heat loss due to excess air entering furnace and moisture accompanying same, T_{11} to T_6	....	....
(104)	= Heat loss due to air and moisture leaking through boiler setting, T_1 to T_6	....	....
(105)	= Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for	....	....

Table 2*d* Heat-Balance Computations for a Steam-Generating Unit Comprising Boiler and Superheater with or without Integral Ecomomizer. Solid Fuels

Item

(92) $= \textit{Item } 26 \text{ (or 27)}$

(93) $= \textit{Item } 85 \text{ (or 86)} \times 970.4$

(94) $= (H_1 - H) \times \textit{Item } 84$

(95) $= (1090.7 + 0.455\, T_{11} - T_{12}) \times \dfrac{(\textit{Item } 25 + 9 \times \textit{Item } 31)}{100} + (\textit{Item } 44 - \textit{Item } 83) \times \textit{Item } 46 \times 0.455 \times (T_{11} - T_4)$

(96) $= \textit{Item } 44 \times (T_{11} - T_4) \times 0.24$*

(97) $= \textit{Item } 95 + \textit{Item } 96$

(98) $= \dfrac{\textit{Item } 81 - \textit{Item } 24}{100} \times 14600$

(99) $= \dfrac{W \times (T_{14} - T_{13})}{\textit{Item } 70 \text{ (or 71)}}$

This item can be determined only in plants where ash and refuse are discharged into water.

(100) $= \dfrac{CO}{CO_2 + CO} \times \textit{Item } 83 \times 10160$ (Use data from *Item* 37)

(101) $= (\textit{Item } 40 - \textit{Item } 44) \times (T_{11} - T_4) \times 0.24 + (\textit{Item } 46 \times 0.455)$

(102) $= (T_6 - T_{11}) \times \left\{ \textit{Item } 44 \times 0.24 + \left[(\textit{Item } 44 - \textit{Item } 83) \times \textit{Item } 46 + \dfrac{\textit{Item } 25 + 9 \times \textit{Item } 31}{100} \right] \times 0.455 \right\}$

(103) $= (\textit{Item } 40 - \textit{Item } 44) \times (T_6 - T_{11}) \times (0.24 + \textit{Item } 46 \times 0.455)$

(104) $= (\textit{Item } 41 - \textit{Item } 40) \times (T_6 - T_1) \times (0.24 + \textit{Item } 46 \times 0.455)$

(105) $= \textit{Item } 92 - \text{Sum of } \textit{Items } 93, 95, 96, \text{ and } 98 \text{ to } 104, \text{ inclusive}$

*Note—*Items* 96, 101, 102, 103 and 104. 0.24 is the value in common use for the specific heat of dry flue gases. This value is not exactly correct and if extreme accuracy is desired the true specific heat should be calculated from the gas analysis.

Note—*Items* 95, 102 and 104. These formulas are correct only when the total moisture in the gases is less than that necessary to saturate the gases of the final temperatures indicated. If the relation of moisture and temperature is such that some moisture will be condensed, these items should be corrected for the heat given up by the condensing vapor.

Table 3*b* Heat Balance of Steam-Generating Unit Comprising Boiler, Superheater, and Economizer. Solid Fuels

Item	Heat Values	B.t.u.	Per cent
(92)	= Heat per lb. coal as fired (high heating value)	....	....
(93)	= Heat absorbed by water and steam in boiler and superheater	....	....
(94)	= Heat absorbed by steam in superheater	....	....
(95)	= Heat absorbed by water in economizer	....	....
	Unavoidable Losses		
(96)	= Heat loss due to moisture in coal, moisture accompanying theoretical air, and water from combustion of hydrogen, up to T_{10}	....	....
(97)	= Heat loss due to theoretical dry gases, T_4 to T_{10}	....	....
(98)	= Total unavoidable losses	....	....
	Other Losses		
(99)	= Heat loss due to combustible in refuse	....	....

		B.t.u.	Per cent
(100)	= Heat loss due to sensible heat in refuse, cinders, and soot	....	....
(101)	= Heat loss due to unburned gaseous combustibles	....	....
(102)	= Heat loss due to excess air entering furnace and moisture accompanying same, T_4 to T_{10}	....	....
(103)	= Heat loss due to theoretical dry gases, moisture in coal, moisture accompanying theoretical air and water from combustion of hydrogen, T_{10} to T_7	....	....
(104)	= Heat loss due to excess air entering furnace and moisture accompanying same, T_{10} to T_7	....	....
(105)	= Heat loss due to air and moisture leaking through boiler setting, T_1 to T_7	....	....
(106)	= Heat loss due to air and moisture leaking through economizer setting, T_1 to T_7	....	....
(107)	= Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for	....	....
	Economizer		
(108)	= Heat available to economizer in flue gases including moisture from T_6 to T_{10}	....	....
(109)	= Efficiency of economizer	....	....

Table 3d Heat-Balance Computations for a Steam-Generating Unit Comprising Boiler, Superheater, and Economizer. Solid Fuels

Item

(92) = *Item* 26 (or 27)

(93) = *Item* 85 (or 86) × 970.4

(94) = $(H_1 - H) \times$ *Item* 84

(95) = $(h - h_1) \times$ *Item* 84

$$(96) = (1090.7 + 0.455T_{10} - T_{12}) \times \left(\frac{Item\ 25 + 9 \times Item\ 31}{100}\right) + (Item\ 44 - Item\ 83) \times Item\ 46 \times 0.455 \times (T_{10} - T_4)$$

(97) = *Item* 44 × $(T_{10} - T_4) \times 0.24$*

(98) = *Item* 96 + *Item* 97

$$(99) = \frac{(Item\ 81 - Item\ 24) \times 14600}{100}$$

$$(100) = \frac{W \times (T_{14} - T_{13})}{Item\ 70\ (\text{or}\ 71)}$$

This item can be determined only in plants where ash and refuse are discharged into water.

$$(101) = \frac{CO}{CO_2 + CO} \times Item\ 83 \times 10{,}160. \quad \text{(Use data from Item 38.)}$$

$$(102) = (Item\ 40 - Item\ 44) \times (T_{10} - T_4) \times (0.24 + Item\ 46 \times 0.455)$$

$$(103) = (T_7 - T_{10}) \times \left\{Item\ 44 \times 0.24 + \left[(Item\ 44 - Item\ 83) \times Item\ 46 + \frac{Item\ 25 + 9 \times Item\ 31}{100}\right] \times 0.455\right\}$$

$$(104) = (Item\ 40 - Item\ 44) \times (T_7 - T_{10}) \times (0.24 + Item\ 46 \times 0.455)$$

$$(105) = (Item\ 41 - Item\ 40) \times (T_7 - T_1) \times (0.24 + Item\ 46 \times 0.455)$$

$$(106) = (Item\ 42 - Item\ 41) \times (T_7 - T_1) \times (0.24 + Item\ 46 \times 0.455)$$

(107) = *Item* 92 − Sum of *Items* 93, 95 to 97 and 99 to 106, inclusive

$$(108) = (T_6 - T_{10}) \times \left\{Item\ 41 \times 0.24 + \left[(Item\ 41 - Item\ 83) \times Item\ 46 + \frac{Item\ 25 + 9 \times Item\ 31}{100}\right] \times 0.455\right\}$$

$$(109) = \frac{Item\ 95}{Item\ 108}$$

*Note—*Items* 97, 102, 103, 104, 105, 106, 107, 108. 0.24 is the value in common use for the specific heat of dry flue gases. This value is not exactly correct and if extreme accuracy is desired the true specific heat should be calculated from the gas analysis.

*Note—*Items* 96, 103, 105, 106 and 108. These formulas are correct only when the total moisture in the gases is less than that necessary to saturate the gases of the final temperatures indicated. If the relation of moisture and temperature is such that some moisture will be condensed, these items should be corrected for the heat given up by the condensing vapor.

Table 4b Heat Balance of Steam-Generating Unit Comprising Boiler, Superheater, Economizer, and Air Heater. Solid Fuels

Item	Heat Values	B.t.u.	Per cent
(92)	Heat per lb. coal (as fired, dry) (high heating value)	....	....
(93)	Heat absorbed by water and steam in boiler and superheater	....	....
(94)	Heat absorbed by steam in superheater	....	....
(95)	Heat absorbed by water in economizer	....	....
	Losses		
(96)	Heat loss due to combustible in refuse	....	....
(97)	Heat loss due to sensible heat in refuse	....	....
(98)	Heat loss due to incomplete combustion of carbon	....	....
(99)	Heat loss due to theoretical dry gases, T_2 to T_8	....	....
(100)	Heat loss due to moisture in coal, moisture accompanying theoretical air, and water from combustion of hydrogen, up to T_8	....	....
(101)	Heat loss due to excess air and accompanying moisture entering furnace, T_2 to T_8	....	....
(102)	Heat loss due to air and moisture leaking through boiler setting, T_1 to T_8	....	....
(103)	Heat loss due to air and moisture leaking through economizer setting, T_1 to T_8	....	....
(104)	Heat loss due to air and moisture leaking through air heater setting, T_1 to T_8	....	....
(105)	Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for	....	....
	Economizer		
(106)	Heat available to economizer in flue gases including moisture, T_6 to T_{10}	....	....
(107)	Efficiency of economizer	....	....
	Air Heater		
(108)	Heat available to air heater in flue gases including moisture, T_7 to T_2	....	....
(109)	Heat absorbed by air heater	....	....
(110)	Efficiency of air heater	....	....

Note—If unit does not include economizer do not fill out Items 95, 103, 106 and 107. If data are available for further segregation of losses, other items may be added.

Table 4d Heat-Balance Computations for Steam-Generating Unit Comprising Boiler, Superheater, Economizer, and Air Heater. Solid Fuels

Item

(92) = *Item* 26 (or 27)

(93) = *Item* 85 (or 86) × 970.4

(94) = $(H_1 - H) \times$ *Item* 84

(95) = $(h - h_1) \times$ *Item* 84

$$(96) = \frac{(Item\ 81 - Item\ 24) \times 14600}{100}$$

$$(97) = \frac{W(T_{14} - T_{13})}{Item\ 70\ (\text{or}\ 71)}$$

This item can be determined only in plants where ash and refuse are discharged into water.

$$(98) = \frac{CO}{CO_2 + CO} \times Item\ 83 \times 10160$$

(99) = *Item* 44 × $(T_8 - T_2) \times 0.24$*

$$(100) = (1090.7 + 0.455T_8 - T_{12}) \times \frac{Item\ 25 + 9 \times Item\ 31}{100} + (Item\ 44 - Item\ 83) \times Item\ 46 \times 0.455 \times (T_8 - T_2)$$

$$(101) = (Item\ 40 - Item\ 44) \times (T_8 - T_2) \times (0.24 + Item\ 46 \times 0.455)$$

$$(102) = (Item\ 41 - Item\ 40) \times (T_8 - T_1) \times (0.24 + Item\ 46 \times 0.455)$$

$$(103) = (Item\ 42 - Item\ 41) \times (T_8 - T_1) \times (0.24 + Item\ 46 \times 0.455)$$

$$(104) = (Item\ 43 - Item\ 42) \times (T_8 - T_1) \times (0.24 + Item\ 46 \times 0.455)$$

(105) = *Item* 92 − The sum of *Items* 93, 95 to 104, inclusive, and *Item* 109

$$(106) = (T_6 - T_{10}) \times \left\{Item\ 41 \times 0.24 + \left[(Item\ 41 - Item\ 83) \times Item\ 46 + \frac{Item\ 25 + 9 \times Item\ 31}{100}\right] \times 0.455\right\}$$

$$(107) = \frac{Item\ 95}{Item\ 106}$$

$$(108) = (T_7 - T_2) \times \left\{Item\ 42 \times 0.24 + \left[(Item\ 42 - Item\ 83) \times Item\ 46 + \frac{Item\ 25 + 9 \times Item\ 31}{100}\right] \times 0.455\right\}$$

$$(109) = (T_3 - T_2) \times Item\ 45 \times (0.24 + Item\ 46 \times 0.455)$$

$$(110) = \frac{Item\ 109}{Item\ 108}$$

*Note—*Items* 99, 101, 102, 103, 104, 108 and 109. 0.24 is the value in common use for the specific heat of dry flue gases. This value is not exactly correct and if extreme accuracy is desired the true specific heat should be calculated from the gas analysis.

Note—*Items* 100, 102, 103, 104, 106, 108, and 109. These formulas are correct only when the total moisture in the gases is less than that necessary to saturate the gases of the final temperatures indicated. If the relation of moisture and temperature is such that some moisture will be condensed, these items should be corrected for the heat given up by the condensing vapor.

Table 5a Data and Results. Test of Stationary Steam-Generating Unit. Liquid Fuels—As Fired—Moisture Free

General Information

(1) Date of test
(2) Location of plant
(3) Owner of plant
(4) Maker and type of boiler
(5) Maker and type of superheater
(6) Maker and type of economizer
(7) Maker and type of air heater
(8) Maker and type of fuel-burning equipment
(9) Test conducted by
(10) Object of test

Description, Dimensions, Etc.

(11) Boiler heating surface .... sq. ft.
(12) Superheater surface .... sq. ft.
(13) Economizer surface .... sq. ft.
(14) Air-heater surface .... sq. ft.
(15) Number of burners
(16) Draft
(17) Fuel
(18) Area of furnace floor .... wide .... deep .... sq. ft.
(19) Height of furnace floor to nearest heating surface .... ft.
(20) Furnace volume per sq. ft. boiler heating surface .... cu. ft.

Fuel and Gas Analyses and Data

Fuel—As Fired—Moisture-Free

(21) Moisture .... per cent
(22) B.t.u. per lb. as fired .... B.t.u.
(23) B.t.u. per lb. moisture free .... B.t.u.
(24) Flash point .... deg. fahr.
(25) Carbon .... per cent
(26) Hydrogen .... per cent
(27) Oxygen .... per cent
(28) Nitrogen .... per cent
(29) Baumé gravity .... deg.

Gas

(30) Gas analysis, furnace: Per cent CO_2.... O_2.... CO.... N_2.... SO_2....
(31) Gas analysis, boiler outlet: Per cent CO_2.... O_2.... CO.... N_2.... SO_2....
(32) Gas analysis, economizer outlet: Per cent CO_2.... O_2.... CO.... N_2.... SO_2....
(33) Gas analysis, air-heater outlet: Per cent CO_2.... O_2.... CO.... N_2.... SO_2....
(34) Dry gas per lb. fuel, furnace (as fired, moisture free) .... lb.
(35) Dry gas per lb. fuel, boiler outlet (as fired, moisture free) .... lb.
(36) Dry gas per lb. fuel, economizer outlet (as fired, moisture free) .... lb.
(37) Dry gas per lb. fuel, air heater outlet (as fired, moisture free) .... lb.
(38) Dry gas per lb. fuel, theoretical (as fired, moisture free) .... lb.
(39) Air supplied per lb. fuel furnace (as fired, moisture free) .... lb.

Pressures and Drafts

(40) Moisture in air .... lb. per lb. air
(41) Steam pressure by gage, boiler .... lb. per sq. in.
(42) Steam pressure by gage, superheater outlet .... lb. per sq. in.
(43) Pressure of fuel at burners .... lb. per sq. in.
(44) Pressure of air for combustion at burners .... in. of water
(45) Draft in furnace .... in. of water
(46) Draft at boiler outlet .... in. of water
(47) Draft at economizer outlet .... in. of water
(48) Draft at air-heater outlet .... in. of water

Temperatures

(49) Steam temperature .... deg. fahr.
(50) Moisture in steam .... per cent
(51) Superheat .... deg. fahr.
(52) Temperature of air surrounding boiler, T_1 .... deg. fahr.
(53) Temperature of air entering air heater, T_2 .... deg. fahr.
(54) Temperature of air leaving air heater, T_3 .... deg. fahr.
(55) Temperature of air for combustion, T_4 .... deg. fahr.
(56) Temperature of furnace, T_5 .... deg. fahr.
(57) Temperature of gases leaving boiler, T_6 .... deg. fahr.
(58) Temperature of gases leaving economizer, T_7 .... deg. fahr.
(59) Temperature of gases leaving air heater, T_8 .... deg. fahr.
(60) Temperature of feedwater entering boiler, T_9 .... deg. fahr
(61) Temperature of feedwater entering economizer, T_{10} .... deg. fahr
(62) Temperature of water in boiler at point where gases leave boiler, T_{11} .... deg. fahr.
(63) Temperature of fuel at burner, T_{12} .... deg. fahr.

Hourly Quantities

(64) Duration of test .... hr.
(65) Fuel as fired per hour .... lb.
(66) Fuel per hour, moisture free .... lb.
(67) Fuel per cu. ft. furnace volume per hour, as fired .... lb.
(68) Fuel per burner, per hour as fired, moisture free .... lb
(69) Fuel per burner, per hour, moisture free .... lb.
(70) Fuel per cu. ft. furnace volume, moisture free .... lb.
(71) Actual water per hour .... lb.
(72) Factor of evaporation ....
(73) Equivalent water per hour .... lb.
(73a) Boiler horsepower, average .... hp.

Evaporation

(74) Actual evaporation per lb. fuel, as fired, moisture free .... lb.
(75) Equivalent evaporation per lb. fuel, as fired .... lb.
(76) Equivalent evaporation per lb. fuel, moisture free .... lb.
(77) Equivalent evaporation per sq. ft. heating surface per hour .... lb.

Horsepower

(78) Number of 1000 B.t.u. absorbed per sq. ft. of boiler heating surface per hour .... B.t.u.
(79) Per cent rating .... per cent

Efficiency

(80) Efficiency of boiler, superheater, furnace, burners, and air heater .... per cent
(81) Efficiency including economizer .... per cent

Table 5b Heat Balance of a Steam-Generating Unit, Short Form. Liquid Fuels

Item		B.t.u.	Per cent
(82)	Heat absorbed by water and steam in boiler and superheater	....	....
(83)	Heat absorbed by water in economizer	....	....
(84)	Heat loss due to moisture in fuel	....	....
(85)	Heat loss due to water from combustion of hydrogen	....	....
(86)	Heat loss due to moisture in air	....	....
(87)	Heat loss due to dry chimney gases	....	....
(88)	Heat loss due to incomplete combustion of carbon	....	....
(89)	Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for	....	....

Table 5c Computations for Test of Stationary Steam-Generating Unit. Liquid Fuel

Explanation of Symbols

Wherever CO_2, O_2, CO, and N_2 are used they are the percentages by volume of these constituents in the gases of combustion.

H = total heat (in B.t.u. per lb.) of saturated steam at the boiler outlet pressure
H_1 = total heat (in B.t.u. per lb.) of superheated steam at the superheater outlet pressure
h = total heat (in B.t.u. per lb.) in feedwater at boiler inlet
h_1 = total heat (in B.t.u. per lb.) in feedwater at economizer inlet
L = latent heat (in B.t.u. per lb.) in steam at pressure in steam main
t_2 = temperature of steam after expansion in calorimeter.

General

If test is on a moisture-free basis, draw a line through "as fired" wherever the words "as fired dry" appear together and vice versa. Whichever basis is chosen must be followed throughout. Percentage results in heat balance will be the same in either case.

Items 11 to 14—Heating surface shall consist of that portion of the surface of the heat-transfer apparatus exposed to both the gases being cooled and the fluid being heated at the same time (computed on the gas side).

Item 16—State whether natural, forced, induced or a combination of one or more kinds of draft is employed.

Item 17—State general class of fuel, give district where produced.

Item 20—Furnace volume is the cubic space provided for the combustion of fuel before the products of combustion pass through any heating surface.

Items 21 to 29 – As-fired-analysis items =

$$\text{dry-analysis items} \times \left(1 - \frac{\textit{Item } 21}{100}\right)$$

$$\textit{Items } 34 \text{ to } 37 = \frac{11\,CO_2 + 8\,O_2 + 7(CO + N_2)}{3(CO_2 + CO)} \times \textit{Item } 83$$

Use data from Items 30 to 33.

$$\textit{Item } 38 = \frac{12.52 \times \textit{Item } 25 + 26.56 \times \textit{Item } 26 + \textit{Item } 28}{100}$$

$$\textit{Item } 39 = \textit{Item } 34 + \frac{9 \times \textit{Item } 26}{100} - 1$$

Item 40—For methods of determination see code on Instruments and Apparatus, Par. —.

Item 50—Either determine from charts or the following formula:

$$100 \times \frac{H - 1150.4 - 0.47 \times (t_2 - 212)}{L}$$

$$\textit{Item } 72 \quad \text{(For saturated or wet steam)} = \frac{H - \dfrac{L \times \textit{Item } 55}{100} - h}{970.4}$$

$$\text{(For superheated steam)} = \frac{H_1 - h}{970.4}$$

$$\textit{Item } 73 = \textit{Item } 71 \times \textit{Item } 72$$

$$\textit{Item } 73a = \frac{\textit{Item } 73}{34.5}$$

$$\textit{Item } 74 = \frac{\textit{Item } 71}{\textit{Item } 65 \text{ (or 66)}}$$

$$\textit{Item } 75 = \frac{\textit{Item } 73}{\textit{Item } 65}$$

$$\textit{Item } 76 = \frac{\textit{Item } 73}{\textit{Item } 66}$$

$$\textit{Item } 77 = \frac{\textit{Item } 73}{\textit{Item } 11}$$

$$\textit{Item } 78 = \frac{\textit{Item } 73 \times 970.4}{\textit{Item } 11}$$

$$\textit{Item } 79 = \frac{\textit{Item } 73\text{a} \times 10}{\textit{Item } 11}$$

$$\textit{Item } 80 = \frac{\textit{Item } 75 \text{ (or 76)} \times 970.4}{\textit{Item } 22 \text{ (or 23)}}$$

$$\textit{Item } 81 = \frac{\textit{Item } 75 \text{ (or 76)} \times 970.4 + (h - h_1) \times \textit{Item } 74}{\textit{Item } 22 \text{ (or 23)}}$$

TABLE 5*l* HEAT-BALANCE COMPUTATIONS FOR STEAM-GENERATING UNIT—SHORT FORM. LIQUID FUELS

Item

(82) = *Item* 75 (or 76) × 970.4

(83) = $(h - h_1) \times$ *Item* 74

(84) $= \dfrac{\textit{Item } 21}{100} \times (1090.7 + 0.455\ T_6 - T_{12})$

(85) $= \dfrac{\textit{Item } 26 \times 9}{100} \times (1090.7 + 0.455\ T_6 - T_{12})$

If economizer is installed without air heater, substitute T_7 for T_6. If air heater is installed, substitute T_8 for T_6 in Items 84, 85, 86, and 87.

(86) = *Item* 39 × *Item* 40 × 0.455 × $(T_6 - T_4)$.

This item is small and is frequently included in Item 89.

(87) = *Item* 35 (or 36 or 37) × 0.24 × $(T_6 - T_1)$.

If boiler and superheater use Item 35, if economizer use Item 36, if air heater use Item 37.

(88) $= \dfrac{CO}{CO_2 + CO} \times \textit{Item } 25 \times 10160.$

(89) = *Item* 22 (or 23) − Sum of *Items* 82 to 88, inclusive.

TABLE 6*b* HEAT BALANCE OF STEAM-GENERATING UNIT COMPRISING BOILER AND SUPERHEATER, WITH OR WITHOUT INTEGRAL ECONOMIZER. LIQUID FUELS

Item	HEAT VALUES	B.t.u.	Per cent
(82)	= Heat per lb. fuel as fired (high heating value)	....	....
(83)	= Heat absorbed by water and steam in boiler and superheater	....	....
(84)	= Heat absorbed by steam in superheater	....	....
	UNAVOIDABLE LOSSES		
(85)	= Heat loss due to moisture in fuel, moisture accompanying theoretical air, and water from combustion of hydrogen, up to T_{11}	....	....
(86)	= Heat loss due to theoretical dry gases, T_4 to T_{11}	....	....
(87)	= Total unavoidable losses	....	....
	OTHER LOSSES		
(88)	= Heat loss due to incomplete combustion of carbon	....	....
(89)	= Heat loss due to excess air entering furnace and moisture accompanying same, T_4 to T_{11}	....	....
(90)	= Heat loss due to theoretical dry gases, moisture in fuel, moisture accompanying theoretical air, and water from combustion of hydrogen, T_{11} to T_6	....	....
(91)	= Heat loss due to excess air entering furnace and moisture accompanying same, T_{11} to T_6	....	....
(92)	= Heat loss due to air and moisture leaking through boiler setting, T_1 to T_6	....	....
(93)	= Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for	....	....

TABLE 6*d* HEAT-BALANCE COMPUTATIONS FOR STEAM-GENERATING UNIT COMPRISING BOILER AND SUPERHEATER, WITH OR WITHOUT INTEGRAL ECONOMIZER. LIQUID FUELS

Item

(82) = *Item* 22 (or 23)

(83) = *Item* 75 (or 76) × 970.4

(84) = $(H_1 - H) \times$ *Item* 74

(85) $= (1090.7 + 0.455\ T_{11} - T_{12}) \times \dfrac{\textit{Item } 21 + 9 \times \textit{Item } 26}{100} + (\textit{Item } 38 - \textit{Item } 25) \times \textit{Item } 40 \times 0.455 \times (T_{11} - T_4)$

(86) = *Item* 38 × $(T_{11} - T_4)$ × 0.24*

(87) = *Item* 85 + *Item* 86

(88) $= \dfrac{CO}{CO_2 + CO} \times \textit{Item } 25 \times 10160.$ (Use data from Item 31.)

(89) = (*Item* 34 − *Item* 38) × $(T_{11} - T_4)$ × (0.24 + *Item* 40 × 0.455)

(90) $= (T_6 - T_{11}) \times \left\{ \textit{Item } 38 \times 0.24 + \left[(\textit{Item } 38 - \textit{Item } 25) \times \textit{Item } 40 + \dfrac{\textit{Item } 21 + 9 \times \textit{Item } 26}{100} \right] \times 0.455 \right\}$

(91) = (*Item* 34 − *Item* 38) × $(T_{11} - T_6)$ × (0.24 + *Item* 40 × 0.455)

(92) = (*Item* 35 − *Item* 34) × $(T_6 - T_1)$ × (0.24 + *Item* 40 × 0.455)

(93) = *Item* 82 − Sum of *Items* 83, 85, 86 and 88 to 92 inclusive.

* NOTE—*Items* 86, 89, 90, 91, 92. 0.24 is the value in common use for the specific heat of dry flue gases. This value is not exactly correct and if extreme accuracy is desired the true specific heat should be calculated from the gas analysis.

NOTE—*Items* 85, 89, 90, 91 and 92. These formulas are correct only when the total moisture in the gases is less than that necessary to saturate the gases of the final temperatures indicated. If the relation of moisture and temperature is such that some moisture will be condensed, these items should be corrected for the heat given up by the condensing vapor.

TABLE 7*b* HEAT BALANCE OF A STEAM-GENERATING UNIT COMPRISING BOILER, SUPERHEATER, AND ECONOMIZER. LIQUID FUELS

Item	HEAT VALUES	B.t.u.	Per cent
(82)	Heat per lb. fuel, as fired (higher heating value)	....	....
(83)	Heat absorbed by water and steam in boiler and superheater	....	.. .
(84)	Heat absorbed by steam in superheater	....	.. .
(85)	Heat absorbed by water in economizer	....	....
	UNAVOIDABLE LOSSES		
(86)	Heat loss due to moisture in fuel, moisture accompanying theoretical air from combustion of hydrogen, up to T_{10}	....	....
(87)	Heat loss due to theoretical dry gases, T_4 to T_{10}	....	....
(88)	Total unavoidable losses	....	....
	OTHER LOSSES		
(89)	Heat loss due to incomplete combustion of carbon	....	....
(90)	Heat loss due to excess air entering furnace and moisture accompanying same, T_4 to T_{10}	....	....
(91)	Heat loss due to theoretical dry gases, moisture in fuel, moisture accompanying theoretical air, and water from combustion of hydrogen, T_{10} to T_7	....	....
(92)	Heat loss due to excess air entering furnace and moisture accompanying same, T_{10} to T_7	....	....
(93)	Heat loss due to air and moisture leaking through boiler setting, T_1 to T_7	....	....
(94)	Heat loss due to air and moisture leaking through economizer setting, T_1 to T_7	....	....
(95)	Heat loss due to unconsumed hydrogen and hydrocarbons, radiations and unaccounted for	....	....
	ECONOMIZER		
(96)	Heat available to economizer in flue gases, including moisture, T_6 to T_{10}	....	....
(97)	Efficiency of economizer	....	....

TABLE 7*d* HEAT-BALANCE COMPUTATIONS FOR STEAM-GENERATING UNIT COMPRISING BOILER, SUPERHEATER, AND ECONOMIZER. LIQUID FUELS

Item

(82) = *Item* 22 (or 23)

(83) = *Item* 75 (or 76) × 970.4

(84) = $(H_1 - H) \times$ *Item* 74

(85) = $(h - h_1) \times$ *Item* 74

(86) $= (1090.7 + 0.455\ T_{10} - T_{12}) \times \left(\dfrac{\textit{Item } 21 + 9 \times \textit{Item } 26}{100}\right) + (\text{Item } 38 - \textit{Item } 25) \times \textit{Item } 40 \times 0.455 \times (T_{10} - T_4)$

(87) = *Item* 38 × $(T_{10} - T_4)$ × 0.24*

(88) = *Item* 86 + *Item* 87

(89) $= \dfrac{CO}{CO_2 + CO} \times \textit{Item } 25 \times 10160.$ (Use data from Item 31)

(90) = (*Item* 34 − *Item* 38) × $(T_{10} - T_4)$ × (0.24 + *Item* 40 × 0.455)

(91) $= (T_7 - T_{10}) \times \left\{ \textit{Item } 38 \times 0.24 + \left[(\textit{Item } 38 - \textit{Item } 25) \times \textit{Item } 40 + \dfrac{\textit{Item } 21 + 9 \times \textit{Item } 26}{100} \right] \times 0.455 \right\}$

(92) = (*Item* 34 − *Item* 38) × $(T_7 - T_{10})$ × (0.24 + *Item* 40 × 0.455)

(93) = (*Item* 35 − *Item* 34) × $(T_7 - T_{10})$ × (0.24 + *Item* 40 × 0.455)

(94) = (*Item* 36 − *Item* 35) × $(T_7 - T_{10})$ × (0.24 + *Item* 40 × 0.455)

(95) = *Item* 82 − Sum of *Items* 83, 85 to 94, inclusive.

$$(96) = (T_6 - T_{10}) \times \left\{ Item\ 35 \times 0.24 + \left[(Item\ 35 - Item\ 25) \times Item\ 40 + \frac{Item\ 21 + 9 \times Item\ 26}{100} \right] \times 0.455 \right\}$$

$$(97) = \frac{Item\ 85}{Item\ 96}$$

* Note—*Items* 87, 90, 91, 92, 93, 94 and 96. 0.24 is the value in common use for the specific heat of dry gases. This value is not exactly correct and if extreme accuracy is desired the true specific heat should be calculated from the gas analysis.

Note—*Items* 86, 90, 91, 92, 93, 94 and 96. These formulas are correct only when the total moisture in the gases is less than that necessary to saturate the gases of the final temperatures indicated. If the relation of moisture and temperature is such that some moisture will be condensed, these items should be corrected for the heat given up by the condensing vapor.

Table 8*b* Heat Balance of a Steam-Generating Unit Comprising Boiler, Superheater, Economizer and Air Heater. Liquid Fuels

Item	Heat Values	B.t.u.	Per cent
(82)	Heat per lb. fuel, as fired (higher heating value)........................	....	....
(83)	Heat absorbed by water and steam in boiler and superheater..................	...	...
(84)	Heat absorbed by steam in superheater ...	....	....
(85)	Heat absorbed by water in economizer	..	..
	Losses		
(86)	Heat loss due to incomplete combustion of carbon........................	....	..
(87)	Heat loss due to theoretical dry gases, T_2 to T_8........................	....	..
(88)	Heat loss due to moisture in fuel, moisture accompanying theoretical air and water from the combustion of hydrogen, up to T_8	....	..
(89)	Heat loss due to excess air entering furnace and moisture accompanying same, T_2 to T_8	....	....
(90)	Heat loss due to air and moisture leaking through boiler setting, T_1 to T_8..........	....	....
(91)	Heat loss due to air and moisture leaking through economizer setting, T_1 to T_8......	....	....
(92)	Heat loss due to air and moisture leaking through air heater setting, T_1 to T_8......	....	....
(93)	Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for...	....	...
	Economizer		
(94)	Heat available to economizer in flue gases, including moisture, T_7 to T_2..	....	...
(95)	Efficiency of economizer........	....	...
	Air Heater		
(96)	Heat available to air heater in flue gases, including moisture, T_7 to T_2..		
(97)	Heat absorbed by air heater......	....	
(98)	Efficiency of air heater...................	..	..

Note—If unit does not include economizer do not fill out Items 85, 91, 94, 95. If data are available for further segregation of losses, other items may be added.

Table 8*d* Heat-Balance Computations for Steam-Generating Unit Comprising Boiler, Superheater, Economizer, and Air Heater. Liquid Fuels

Item

(82) = *Item* 22 (or 23)

(83) = *Item* 75 (or 76)×970.4

(84) = $(H_1 - H) \times Item\ 74$

(85) = $(h - h_1) \times Item\ 74$

$$(86) = \frac{CO}{CO_2 + CO} \times Item\ 25 \times 10160$$

(87) = *Item* 38 × $(T_8 - T_2)$ × 0.24*

$$(88) = (1090.7 + 0.455\ T_8 - T_{12}) \times \left(\frac{Item\ 21 + 9 \times Item\ 26}{100} \right) + (Item\ 38 - Item\ 25) \times Item\ 40 \times 0.455 \times (T_8 - T_2)$$

(89) = (*Item* 34 − *Item* 38) × $(T_8 - T_2)$ × (0.24 + *Item* 40 × 0.455)

(90) = (*Item* 35 − *Item* 34) × $(T_8 - T_1)$ × (0.24 + *Item* 40 × 0.455)

(91) = (*Item* 36 − *Item* 35) × $(T_8 - T_1)$ × (0.24 + *Item* 40 × 0.455)

(92) = (*Item* 37 − *Item* 36) × $(T_8 - T_1)$ × (0.24 + *Item* 40 × 0.455)

(93) = *Item* 82 − Sum of *Items* 83, 85 to 92, inclusive, and *Item* 97.

$$(94) = (T_6 - T_{10}) \times \left\{ Item\ 35 \times 0.24 + \left[(Item\ 35 - Item\ 25) \times Item\ 40 + \frac{Item\ 21 + 9 \times Item\ 26}{100} \right] \times 0.455 \right\}$$

$$(95) = \frac{Item\ 85}{Item\ 94}$$

$$(96) = (T_7 - T_2) \times \left\{ Item\ 36 \times 0.24 + \left[(Item\ 36 - Item\ 25) \times Item\ 40 + \frac{Item\ 21 + 9 \times Item\ 26}{100} \right] \times 0.455 \right\}$$

(97) = $(T_3 - T_2)$ × *Item* 39 × (0.24+*Item* 40 × 0.455)

$$(98) = \frac{Item\ 97}{Item\ 96}$$

* Note—*Items* 87, 89, 90, 91, 92, 93, 94, and 96. 0.24 is the value in common use for the specific heat of dry flue gases. This value is not exactly correct and if extreme accuracy is desired the true specific heat should be calculated from the gas analysis.

Note—*Items* 88, 89, 90, 91, 92, 93, 94, 96, 97. These formulas are correct only when the total moisture in the gases is less than that necessary to saturate the gases of the final temperatures indicated. If the relation of moisture and temperature is such that some moisture will be condensed, these items should be corrected for the heat given up by the condensing vapor.

Table 9*a* Data and Results of Test of Stationary Steam-Generating Unit. Gaseous Fuels

General Information

(1) Date of test..

(2) Location of plant ....

(3) Owner of plant ....

(4) Maker and type of boiler ....

(5) Maker and type of superheater..........................

(6) Maker and type of economizer..........................

(7) Maker and type of air heater ....

(8) Maker and type of fuel-burning equipment...............

(9) Test conducted by.....................................

(10) Object of test..

Description Dimensions, etc.

(11) Boiler heating surface..............................sq. ft.

(12) Superheater surface.................................sq. ft.

(13) Economizer surface ....sq. ft.

(14) Air heater surface..................................sq. ft.

(15) Number of burners.....................................

(16) Draft...

(17) Fuel..

(18) Area of furnace floor........Wide........Deep........sq. ft.

(19) Height of furnace, floor to nearest heating surface............ft.

(20) Furnace volume per sq. ft. of boiler heating surface......cu. ft.

Fuel and Combustion Products and Data

Fuel Analysis

(21) Moisture ....volume....per cent....weight

(22) Carbon monoxide, CO.........volume....per cent....weight

(23) Hydrogen, H_2.................volume....per cent....weight

(24) Methane, CH_4.................volume....per cent....weight

(25) Acetylene, C_2H_2..............volume....per cent....weight

(26) Ethylene, C_2H_4 ....volume....per cent....weight

(27) Ethane, C_2H_6.................volume....per cent....weight

(28) Hydrogen sulphide, H_2S ....volume....per cent....weight

(29) Oxygen, O_2...................volume....per cent....weight

(30) Nitrogen, N_2.................volume....per cent....weight

(31) Carbon dioxide, CO_2..........volume....per cent....weight

(32) B.t.u. per cu. ft. standard conditions...............B.t.u.

(33) B.t.u. per lb. ....B.t.u.

(34) Weight per cu. ft. standard conditions...................lb.

Combustion Products

(35) Gas analysis, furnace:
Per cent CO_2....O_2....CO....N....SO_2....

(36) Gas analysis, boiler outlet:
Per cent CO_2....O_2....CO....N....SO_2....

(37) Gas analysis, economizer:
Per cent CO_2....O_2....CO....N....SO_2....

(38) Gas analysis, air heater:
Per cent CO_2....O_2....CO....N....SO_2....

(39) Dry gas per lb. fuel, furnace ....lb.

(40) Dry gas per lb. fuel, boiler outlet ....lb.

(41) Dry gas per lb. fuel, economizer outlet ....lb.

(42) Dry gas per lb. fuel, air-heater, outlet ....lb.

(43) Dry gas per lb. fuel, theoretical ....lb.

(44) Air supplied per lb. fuel, furnace ....lb

Pressures and Drafts

(45) Moisture in air..............................lb. per lb. air

(46) Steam pressure by gage, boiler ....lb. per sq. in.

(47) Steam pressure by gage, superheater ....lb. per sq. in.

(48) Pressure of fuel at burners.......................in. of water

(49) Pressure of air for combustion at burners.........in. of water

(50) Draft in furnace.................................in. of water

(51) Draft at boiler outlet...........................in. of water

(52) Draft at economizer outlet.......................in. of water

(53) Draft at air-heater outlet ....in. of water

Temperatures

(54)	Steam temperature	deg. fahr.
(55)	Moisture in steam	per cent
(56)	Superheat	deg. fahr.
(57)	Temperature of air surrounding boiler, T_1.	deg. fahr.
(58)	Temperature of air entering air heater, T_2.	deg. fahr.
(59)	Temperature of air leaving air heater, T_3.	deg. fahr.
(60)	Temperature of air for combustion, T_4.	deg. fahr.
(61)	Temperature of furnace, T_5.	deg. fahr.
(62)	Temperature of gases leaving boiler, T_6.	deg. fahr.
(63)	Temperature of gases leaving economizer, T_7.	deg. fahr.
(64)	Temperature of gases leaving air heater, T_8.	deg. fahr.
(65)	Temperature of feedwater entering boiler, T_9.	deg. fahr.
(66)	Temperature of feedwater entering economizer, T_{10}.	deg. fahr.
(67)	Temperature of water in boiler at point where gases leave boiler, T_{11}.	deg. fahr.
(68)	Temperature of fuel at burner, T_{12}.	deg. fahr.

Hourly Quantities

(69)	Duration of test	hr.
(70)	Fuel gas as fired per hour	lb.
(71)	Fuel gas per hour, standard conditions.	cu. ft.
(72)	Fuel gas per burner per hour	lb.
(73)	Fuel gas per cu. ft. of furnace volume, per hour	lb.
(74)	Actual water per hour	lb.
(75)	Factor of evaporation	
(76)	Equivalent water per hour	lb.
(76a)	Boiler horsepower, average	
(77)	Actual evaporation per lb. fuel	lb.
(78)	Equivalent evaporation per lb. fuel	lb.
(79)	Equivalent evaporation per sq. ft. boiler heating surface per hour	lb.

Horsepower

(80)	Number of 1000 B.t.u. absorbed per sq. ft. of boiler heating surface per hour	B.t.u.
(81)	Per cent rating	per cent

Efficiency

(82)	Efficiency of boiler, superheater, furnace, burners, and air heater	per cent
(83)	Efficiency including economizer	per cent

Table 9b Heat Balance of a Steam-Generating Unit. Short Form. Gaseous Fuels

Item		B.t.u.	Per cent
(84)	Heat absorbed by water and steam in boiler and superheater	....	....
(85)	Heat absorbed by water in economizer	....	....
(86)	Heat loss due to moisture in fuel	....	....
(87)	Heat loss due to water from combustion of hydrogen	....	....
(88)	Heat loss due to moisture in air	....	....
(89)	Heat loss due to dry chimney gases	....	....
(90)	Heat loss due to incomplete combustion of carbon	....	....
(91)	Heat loss due to unconsumed hydrogen and hydrocarbons, radiation and unaccounted for	....	....

Table 9c Computations for Test of Stationary Steam-Generating Unit. Gaseous Fuel

Explanation of Symbols

Wherever CO_2, O_2, CO, and N_2 are used they are the percentages by volume of these constituents in the gases of combustion.

C = carbon content per lb. of fuel gas.

H = total heat (in B.t.u. per lb.) of saturated steam at the boiler outlet pressure.

H_1 = total heat (in B.t.u. per lb.) of superheated steam at the superheater outlet pressure.

h = total heat (in B.t.u. per lb.) in feedwater at boiler inlet.

h_1 = total heat (in B.t.u. per lb.) in feedwater at economizer inlet.

L = latent heat (in B.t.u. per lb.) in steam at pressure in steam main.

t_2 = temperature of steam after expansion in calorimeter.

Item 11 to 14—Heating surface shall consist of that portion of the surface of the heat-transfer apparatus exposed to both the gases being cooled and the fluid being heated at the same time (computed on the gas side).

Item 16—State whether natural, forced, induced or a combination of one or more kinds of draft was employed.

Item 17—State general class of fuel, as blast-furnace gas, by-product coke-oven gas, natural gas, etc. and give district.

Item 20—Furnace volume is the cubic space provided for the combustion of fuel before the products of combustion pass through any heating surface.

Item 22 to 34—Fuel-gas analysis should be reported on dry basis. Where B.t.u. value is calculated it is on dry basis. Where determined on calorimeter should be corrected for moisture. If $T_{12} > T_1$ add mean specific heat $\times$ $(T_{12} - T_1)$ to the calculated B.t.u. value. Standard conditions are 29.92 inches mercury and 32 deg. fahr.

Item 33 = *Item* 32 $\times$ *Item* 34.

$$Item\ 39\text{ to }42 = \frac{11\,CO_2 + 8\,O_2 + 7(CO + N_2)}{3(CO_2 + CO)} \times Item\ 83$$

Use data from Items 35 to 38. $C = {}^3/_7$ *Item* 22 + ${}^3/_4$ *Item* 24 + ${}^{12}/_{11}$ *Item* 25 + ${}^6/_7$ *Item* 26 + ${}^6/_7$ *Item* 27 + ${}^3/_{11}$ *Item* 31 (by weight).

$$Item\ 43 = \frac{346 \times Item\ 22 + 26.56 \times Item\ 23 + 16.03 \times Item\ 24 +}{100}$$
$$\frac{13.60 \times Item\ 25 + 15.52 \times Item\ 26 + 15.33 \times Item\ 27 +}{100}$$
$$\frac{6.58 \times Item\ 28 + Item\ 30 + Item\ 31}{100}\ \text{(by weight)}$$

$$Item\ 44 = Item\ 39 + \frac{9 \times Item\ 23}{100} - 1$$

Item 45—For methods of determination see code on Instruments and Apparatus Par. —.

Item 55—Determine either from charts or the following formula:

$$100 \times \frac{H - 1150.4 - 0.47 \times (t_2 - 212)}{L}$$

$$Item\ 75\quad \text{(For saturated or wet steam)} = \frac{H - \dfrac{L \times Item\ 55}{100} - h}{970.4}$$

$$\text{(For superheated steam)} = \frac{H_1 - h}{970.4}$$

$$Item\ 76 = Item\ 74 \times Item\ 75$$

$$Item\ 76a = \frac{Item\ 76}{34.5}$$

$$Item\ 77 = \frac{Item\ 74}{Item\ 70}$$

$$Item\ 78 = \frac{Item\ 76}{Item\ 70}$$

$$Item\ 80 = \frac{Item\ 76 \times 970.4}{Item\ 11}$$

$$Item\ 81 = \frac{Item\ 76a \times 10}{Item\ 11}$$

$$Item\ 79 = \frac{Item\ 76}{Item\ 11}$$

$$Item\ 80 = \frac{Item\ 76}{34.5}$$

$$Item\ 81 = \frac{Item\ 80 \times 10}{Item\ 11}$$

$$Item\ 82 = \frac{Item\ 78 \times 970.4}{Item\ 33}$$

$$Item\ 83 = \frac{Item\ 78 \times 970.4 + (h - h_1) \times Item\ 77}{Item\ 33}.$$

Table 9d Heat-Balance Computations for Steam-Generating Unit. Short Form—Gaseous Fuels

Item

(84) = *Item* 78 $\times$ 970.4

(85) = $(h - h_1) \times$ *Item* 77

(86) = $\dfrac{Item\ 21}{100} \times (1090.7 + 0.455\,T_6 - T_{12})$

(87) = $\dfrac{Item\ 23 \times 9}{100} \times (1090.7 + 0.455\,T_6 - T_{12})$

If economizer is installed without air heater, substitute T_7 for T_6. If air heater is installed, substitute T_8 for T_6 in Items 86, 87, 88 and 89.

(88) = *Item* 44 $\times$ *Item* 45 $\times$ 0.455 $(T_6 - T_4)$.

This item is small and is frequently included in Item 91.

(89) = *Item* 40 (or 41 or 42) $\times$ 0.24 $\times$ $(T_6 - T_1)$.

If boiler and superheater use Item 40. If economizer use Item 41. If air heater use Item 42.

(90) = $\dfrac{CO}{CO_2 + CO} \times C \times 10160$

(91) = *Item* 33 − Sum of *Items* 84–90, inclusive.

Table 10b Heat Balance of Steam-Generating Unit Comprising Boiler and Superheater, with or without Integral Economizer. Gaseous Fuels

Item	Heat Values	B.t.u.	Per cent
(84)	Heat per lb. fuel as fired (high heating value)	....	....
(85)	Heat absorbed by water and steam in boiler and superheater	....	....
(86)	Heat absorbed by steam in superheater	....	....
	Unavoidable Losses		
(87)	Heat loss due to moisture in fuel, moisture accompanying theoretical air and water from combustion of hydrogen, up to T_{11}	....	....
(88)	Heat loss due to theoretical dry gases, T_4 to T_{11}	....	....
(89)	Total unavoidable losses	....	....

Item	Other Losses	B.t.u.	Per cent
(90)	Heat loss due to incomplete combustion of carbon	....	....
(91)	Heat loss due to excess air entering furnace and moisture accompanying same, T_4 to T_{11}	....	....
(92)	Heat loss due to theoretical dry gases, moisture in fuel, moisture accompanying theoretical air, and water from combustion of hydrogen, T_{11} to T_6	....	....
(93)	Heat loss due to excess air entering furnace and moisture accompanying same, T_{11} to T_6	....	....
(94)	Heat loss due to air and moisture leaking through boiler setting, T_1 to T_6	....	....
(95)	Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for	....	....

Table 10*d* Heat-Balance Computations for Steam-Generating Unit Comprising Boiler and Superheater, with or without Integral Economizer. Gaseous Fuels

Item

(84) = *Item* 33

(85) = *Item* 78 × 970.4

(86) = $(H_1 - H) \times$ *Item* 77

(87) = $(1090.7 + 0.455T_{11} - T_{12}) \times \dfrac{(\textit{Item } 21 + 9 \times \textit{Item } 23)}{100} + (\textit{Item } 43 - C) \times \textit{Item } 43 \times 0.455 \times (T_{11} - T_4)$

(88) = $(\textit{Item } 43 \times T_{11} - T_4) \times 0.24$*

(89) = *Item* 87 + *Item* 88

(90) = $\dfrac{CO}{CO_2 + CO} \times C \times 10160.$ (Use data from Item 81)

(91) = $(\textit{Item } 39 - \textit{Item } 43) \times (T_{11} - T_4) \times (0.24 + \textit{Item } 45 \times 0.455).$

(92) = $(T_6 - T_{11}) \times \left\{\textit{Item } 43 \times 0.24 + \left[(\textit{Item } 43 - C) \times \textit{Item } 45 + \dfrac{\textit{Item } 21 + 9 \times \textit{Item } 23}{100}\right] \times 0.455\right\}$

(93) = $(\textit{Item } 39 - \textit{Item } 43) \times (T_{11} - T_6) \times (0.24 + \textit{Item } 45 \times 0.455)$

(94) = $(\textit{Item } 40 - \textit{Item } 39) \times (T_6 - T_1) \times (0.24 + \textit{Item } 45 \times 0.455)$

(95) = *Item* 84 − Sum of *Items* 85, 87, 88, and 90 to 94, inclusive.

* Note—*Items* 88, 91, 92, 93 and 94. 0.24 is the value in common use for the specific heat of dry flue gases. This value is not exactly correct and if extreme accuracy is desired the true specific heat should be calculated from the gas analysis.

Note—*Items* 87, 91, 92, 93 and 94. These formulas are correct only when the total moisture in the gases is less than that necessary to saturate the gases of the final temperatures indicated. If the relation of moisture and temperature is such that some moisture will be condensed, these items should be corrected for the heat given up by the condensing vapor.

Table 11*b* Heat Balance of a Steam-Generating Unit Comprising Boiler, Superheater, and Economizer. Gaseous Fuels

Item	Heat Values	B.t.u.	Per cent
(84)	Heat per lb. fuel as fired (higher heating value)	....	....
(85)	Heat absorbed by water and sfeam in boiler and superheater	....	....
(86)	Heat absorbed by steam in superheater	....	....
(87)	Heat absorbed by water in economizer	....	....
	Unavoidable Losses		
(88)	Heat loss due to moisture in fuel, moisture accompanying theoretical air and water from combustion of hydrogen, up to T_{10}	....	....
(89)	Heat loss due to theoretically dry gases, T_4 to T_{10}	....	....
(90)	Total unavoidable losses	....	....
	Other Losses		
(91)	Heat loss due to incomplete combustion of carbon	....	....
(92)	Heat loss due to excess air entering furnace and moisture accompanying some T_4 to T_{10}	....	....
(93)	Heat loss due to theoretical dry gases, moisture in fuel, moisture accompanying theoretical air, and water from combustion of hydrogen, T_{10} to T_7	....	....
(94)	Heat loss due to excess air entering furnace and moisture accompanying same, T_{10} to T_7	....	....
(95)	Heat loss due to air and moisture leaking through boiler setting, T_1 to T_7	....	....
(96)	Heat loss due to air and moisture leaking through economizer setting, T_1 to T_7	....	....
(97)	Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for	....	....
	Economizer		
(98)	Heat available to economizer in flue gases, including moisture, T_6 to T_{10}	....	
(99)	Efficiency of economizer	...	. . .

Table 11*d* Heat-Balance Computations for Steam-Generating Unit Comprising Boiler, Superheater, and Economizer. Gaseous Fuels

Item

(84) = *Item* 33

(85) = *Item* 78 × 970.4

(86) = $(H_1 - H) \times$ *Item* 77

(87) = $(h - h_1) \times$ *Item* 77

(88) = $(1090.7 + 0.455T_{10} - T_{12}) \times \left(\dfrac{\textit{Item } 21 + 9 \times \textit{Item } 23}{100}\right) + (\textit{Item } 43 - C) \times \textit{Item } 45 \times 0.455 \times (T_{10} - T_4)$

(89) = $\textit{Item } 43 \times (T_{10} - T_4) \times 0.24$*

(90) = *Item* 88 + *Item* 89

(91) = $\dfrac{CO}{CO_2 + CO} \times C \times 10160.$ (Use data from Item 36.)

(92) = $(\textit{Item } 39 - \textit{Item } 43) \times (T_{10} - T_4) \times (0.24 + \textit{Item } 45 \times 0.455)$

(93) = $(T_7 - T_{10}) \times \left\{\textit{Item } 43 \times 0.24 + \left[(\textit{Item } 43 - C) \times \textit{Item } 45 + \dfrac{\textit{Item } 21 + 9 \times \textit{Item } 23}{100}\right] \times 0.455\right\}$

(94) = $(\textit{Item } 39 - \textit{Item } 43) \times (T^7 - T_{10}) \times (0.24 + \textit{Item } 45 \times 0.455)$

(95) = $(\textit{Item } 40 - \textit{Item } 39) \times (T_7 - T_1) \times (0.24 + \textit{Item } 45 \times 0.455)$

(96) = $(\textit{Item } 41 - \textit{Item } 40) \times (T^7 - T_1) \times (0.24 + \textit{Item } 45 \times 0.455)$

(97) = *Item* 84 − Sum of *Items* 85, 87, to 96, inclusive.

(98) = $(T_6 - T_{10}) \times \left\{\textit{Item } 40 \times 0.24 + \left[(\textit{Item } 40 - C) \times \textit{Item } 45 + \dfrac{\textit{Item } 21 + 9 \times \textit{Item } 23}{100}\right] \times 0.455\right\}$

(99) = $\dfrac{\textit{Item } 87}{\textit{Item } 98}$

* Note—*Items* 89, 92, 93, 94, 95, 96 and 98. 0.24 is the value in common use for the specific heat of dry flue gases. This value is not exactly correct and if extreme accuracy is desired the true specific heat should be calculated from the gas analysis.

Note—*Items* 88, 92, 93, 94, 95, 96 and 98. These formulas are correct only when the total moisture in the gases is less than that necessary to saturate the gases of the final temperatures indicated. If the relation of moisture and temperature is such that some moisture will be condensed, these items should be corrected for the heat given up by the condensing vapor.

Table 12*b* Heat-Balance of a Steam-Generating Unit Comprising Boiler, Superheater, Economizer, and Air Heater. Gaseous Fuels

Item	Heat Values	B.t.u.	Per cent
(84)	Heat per lb. fuel as fired (high heating value)	....	....
(85)	Heat absorbed by water and steam in boiler and superheater	....	....
(86)	Heat absorbed by steam in superheater	....	....
(87)	Heat absorbed by water in economizer	....	....
	Losses		
(88)	Heat loss due to incomplete combustion of carbon	....	....
(89)	Heat loss due to theoretical dry gases, T_2 to T_8	....	....
(90)	Heat loss due to moisture in fuel, moisture accompanying theoretical air, and water from the combustion of hydrogen, up to T_8.	....	....
(91)	Heat loss due to excess air entering furnace and moisture accompanying same, T_2 to T_8	....	....
(92)	Heat loss due to air and moisture leaking through boiler setting, T_1 to T_8	....	....
(93)	Heat loss due to air and moisture leakign through economizer setting, T_1 to T_8	....	....
(94)	Heat loss due to air and moisture leaking through air heater setting, T_1 to T_8	....	....
(95)	Heat loss due to unconsumed hydrogen and hydrocarbons, radiation, and unaccounted for	....	....
	Economizer		
(96)	Heat available to economizer in flue gases including moisture, T_6 to T_{10}	....	....

(*Continued on page 565*)

ENGINEERING RESEARCH

A Department Conducted by the Research Committee of the A.S.M.E.

Research Committee of Engineering Division of National Research Council

THE following research committees of the Division of Engineering of the National Research Council have been corrected to date as follows:

Advisory Board on Highway Research (W. K. HATT, *Director*), A. N. JOHNSON, *Chairman*
Character and Use of Road Materials, H. S. MATTIMORE, *Chairman*
Economic Theory of Highway Improvement, T. R. AGG, *Chairman*
Tractive Resistance of Roads, C. J. TILDEN, *Chairman*
Structural Design of Roads, A. T. GOLDBECK, *Chairman*
Highway Traffic Analysis, G. E. HAMLIN, *Chairman*
Highway Finances, J. D. MCKAY, *Chairman*
American Bureau of Welding (WM. SPRARAGEN, *Secretary*), C. A. ADAMS (*Director*)
Electric Arc Welding, H. M. HOBART, *Chairman*
Gas Welding, S. W. MILLER, *Chairman*
Welding of Storage Tanks, J. C. LINCOLN, *Chairman*
Pressure Vessels, H. L. WHITTEMORE, *Chairman*
Welding Wire Specifications, C. A. MCCUNE, *Chairman*
Training of Welding Operators, J. C. WRIGHT, *Chairman*
Standard Tests for Welds, F. M. FARMER, *Chairman*
Specifications for Steel to be Welded, W. J. BECK, *Chairman*
Resistance Welding, H. LEMP, *Chairman*
Thermit Welding, J. H. DEPPELER, *Chairman*
Welded Rail Joints, G. K. BURGESS, *Chairman*
Electrical Core Losses, A. E. KENNELLY, *Chairman*
Electrical Insulation, JOHN B. WHITEHEAD, *Chairman*
Relation of Quality and Quantity of Illumination to Industry, D. C. JACKSON, *Chairman*
Fatigue Phenomena of Metals, H. F. MOORE, *Chairman*
Hardness Testing of Metals, A. E. BELLIS, *Chairman*
Heat Treatment of Carbon Steel, F. B. FOLEY, *Chairman*
Marine Piling Investigations (W. G. ATWOOD, *Director*), R. T. BETTS, *Chairman*
Molding Sands, R. A. BULL, *Chairman*
Neumann Bands, C. E. MUNROE, *Chairman*
Pulverizing, G. H. CLEVENGER, *Chairman*
Uses of Tellurium and Selenium, V. LENHER, *Chairman*

Résumé of the Month

A—RESEARCH RESULTS

The purpose of this section of Engineering Research is to give the origin of research information which has been completed, to give a résumé of research results with formulas or curves where such may be readily given, and to report results of non-extensive researches which in the opinion of the investigators do not warrant a paper.

Building Materials A3-23. DISINTEGRATION OF CEMENT IN SEA WATER. A paper on this subject was presented by Wm. G. Atwood and A. A. Johnson at the June 13th meeting of the American Society of Civil Engineers. This report is available as a preprint and will appear in the August Proceedings of the American Society of Civil Engineers. It includes a review of literature of cement disintegration and describes foreign experiments, and recommends others in connection with cement in sulphate-bearing waters. A résumé of the paper was presented before the annual symposium of the American Society for Testing Materials on Concrete during the latter part of June.

Chemistry, Industrial A1-23. EXPLOSIVES, THEIR MATERIALS, CONSTITUTION, AND ANALYSIS. See *Explosives and Explosions A2-23.*

Electricity, General A1-23. METHODS OF MEASURING THE PROPERTIES OF ELECTRICAL INSULATING MATERIALS. This paper gives a series of electrical, thermal, chemical, and mechanical test methods which have been found useful in the study of solid electrical insulating materials. The several tests described are those used in obtaining the data previously reported in Technologic Paper No. 216 of the Bureau of Standards entitled Properties of Electrical Insulating Materials of the Laminated Phenol-Methylene Type. The several test methods described are radio-frequency phase difference or power loss, dielectric constant and flash-over voltage, direct-current surface resistivity and volume resistivity, tensile modulus of strength, modulus of elasticity (tensile), proportional limit, modulus of rupture, elasticity (transverse), Brinell hardness, scleroscope hardness, resistance to impact, permanent distortion, density, moisture absorption, machining qualities, thermal expansivity, and the effects of heat, acid, and alkali.

Address Superintendent of Documents, Government Printing Office, Washington, D. C., requesting Bureau of Standards Scientific Paper No. 471. Price 15 cents.

Explosives and Explosions A2-23. EXPLOSIVES, THEIR MATERIALS, CONSTITUTION, AND ANALYSIS. This bulletin is intended to cover present methods employed in the industry and to include all classes of explosives and the materials used in their manufacture. Explosives are here grouped as dynamites, black powders, propellants, detonators, and primers. Some materials are used in practically all these groups; others in only one. To discuss all the materials that have been or that may be used and the methods for their identification and quantitative determination is not feasible, but the methods described will probably suggest ways of examining new mixtures.

This report known as Bulletin 219 of the Bureau of Mines was prepared by Messrs. C. A. Taylor and W. H. Rinkenbach and may be obtained from the Superintendent of Documents, Government Printing Office, Washington, D. C. Price 20 cents.

Heating and Ventilation A1-23. RADIATOR TRAPS. For the past two years the Research Committee of the National Association of Building Owners and Managers has been making an exhaustive study of radiator traps now on the market. Its complete program calls for a report on the construction and functioning of these traps as determined by both laboratory tests and the careful record of experience in building operation.

Realizing the great need for reliable information on this subject the Committee has just published a preliminary report which covers only the first part of its program. This report includes a brief statement of thermodynamic theory; an outline of steam heating in general, with the relation of radiator traps thereto; a drawing and description of each of the principal makes of trap; and a detailed statement of the results of the laboratory tests of each such make.

For copies of the report, which covers 68 pages ($8\frac{1}{2}$ by 11 in.), address Mr. L. B. Ermeling, Executive Secretary of the National Association of Building Owners and Managers. Price \$5.

Internal-Combustion Engines A1-23. GASOLINE SAVED ON TRUCKS BY ADJUSTING CARBURETORS BY EXHAUST-GAS ANALYSIS. These tests were made at the Government Fuel Yard, operated at Washington, D. C., by the Bureau of Mines, Department of the Interior, in order to determine and improve the adjustment of the carburetors on the trucks used for transporting coal from the Fuel Yard to the different Government buildings in Washington. The trucks used range in capacity from $2\frac{1}{2}$ to $7\frac{1}{2}$ tons and the majority of the carburetors were of standard type. At the time the tests were made about ten trucks were in daily use.

Samples of the exhaust gas were taken on the trucks kept in service for summer hauling in order to determine the carburetor adjustment as used. Changes were then made to a more economical adjustment wherever possible, without sacrificing flexibility of operation and power. In every case the adjustments were maintained for maximum power, but were adjusted to the leanest position to give that power. In all but one case the carburetors were found to be adjusted too rich for maximum power and economy. These results are considered in detail in the report.

The actual increase in mileage and saving of gasoline due to the carburetor adjustments made by gas analysis, when the months preceding and following the adjustments are compared, showed an increase in mileage of 22 per cent, and for the second month after adjustment, 16 per cent, and the third month 9 per cent. When the mileage is compared truck for truck, and not taking into consideration the distance each traveled during the month, the increased mileage equaled 24.7, 21.2 and 16.2 per cent, respectively.

The tests show that a portable CO_2 indicator for testing the exhaust gases of a motor vehicle, as used in these tests, gives a positive indication of the carburetor adjustment, removes all guesswork from such adjustment, is perfectly feasible practically, and almost indispensable to a company having ten or more large trucks in service, especially if supplied with adjustable carburetors.

Messrs. G. W. Jones and A. C. Fieldner are the authors of this report which is known as Serial 2487 and may be obtained by addressing H. Foster Bain, Director of the Bureau of Mines, Department of the Interior, Washington, D. C.

Marine Engineering A1-23. DISINTEGRATION OF CEMENT IN SEA WATER. See *Building Materials A3-23.*

Welding A1-23. WELDING OF OIL STORAGE TANKS. The design of a 5000-barrel tank by both the electric-arc and oxy-acetylene welding processes has been completed. A report of the electric-arc method, including specifications, was published in the December, 1922, issue of the American Welding Society. A report on the oxy-acetylene welding method has just been completed and was published in the June, 1923, issue of the Journal of the American Welding Society. The latter report includes photographs of two tanks constructed according to this method.

The general object of this investigation was to design a welded storage tank which will enable the reduction of loss of the lighter oils from leakage and evaporation now accruing in the present riveted construction.

Welding A2-23. APPLICATION OF ARC WELDING IN SHIP CONSTRUCTION. A comprehensive report has been prepared by E. H. Ewertz, general manager of the Moore Plant of Bethlehem Shipbuilding Company, under the guidance of the Electric Arc Welding Committee, and is now being published as a serial in *Marine Engineering.* The report includes cost figures, test data, relative advantages of welding versus riveting, service results of applications, and different designs of welded ships.

B—RESEARCH IN PROGRESS

The purpose of this section of Engineering Research is to bring together those who are working on the same problem for coöperation or conference, to prevent unnecessary duplication of work, and to inform the profession of the investigators who are engaged upon research problems. The addresses of these investigators are given for the purpose of correspondence.

Building Materials B3-23. PENETRATION TESTS FOR THE WORKABILITY OF CONCRETE MIXTURES. The laboratory work in connection with the development of a penetration test for the workability of concrete mixtures has recently been completed at the Bureau of Standards.

The outstanding results obtained from the penetration test in this investigation are: (*a*) the relative effects of celite, kaolin, hydrated lime, and other admixtures upon the workability of the concrete have been determined; (*b*) the workability of concrete mixture varies only moderately with change in consistency or flow and is more dependent upon the character and proportions of the solid ingredients than upon the quantity of mixing mortar; (*c*) the workability of concrete mixtures shows a maximum of medium-wet consistency; (*d*) the workability of concrete mixtures depends upon two factors, segregation and lubrication, either one of which may be controlled by suitable changes in the ingredients of the concrete.

Fluid Flow B3-23. INVESTIGATION OF ORIFICE GAS METERS. For several months the Bureau of Standards has had under way the preliminary arrangements for an investigation of the performance of orifice meters. The investigation will be limited to a study of the orifice meter of the type used in the commercial measuring of gas, the principal problem being to determine the discharge coefficient under all the variable circumstances which may occur within the range of commercial or engineering practice.

Up to the present time only a few preliminary runs have been made. During these runs approximate checks were made of the discharge coefficients of the flow nozzles which are to be used in the final measurement. These runs have also served to bring out defects in the equipment and have thus furnished a basis for making alterations and improvements. It is expected that actual tests will be started within a short time.

Gases B3-23. INVESTIGATION OF ORIFICE GAS METERS. See *Fluid Flow B3-23.*

Hardness B2-23. STEEL FOR BRINELL BALLS. In measuring the hardness of metals by the Brinell method, a hardened steel ball is forced into the specimen by hydraulic pressure, the amount of penetration serving as an indication of the hardness of the sample. Difficulty has been found in measuring the Brinell hardness of steel having a hardness over 500 B.h.n. An attempt has been made by the Bureau of Standards for the past 3 or 4 years to obtain a very hard steel which will carry the load of 3000 kg. without fracture, but up to the present without success. Tungsten carbide has been suggested, but it has been impossible to obtain this material in suitable condition in either this country or Germany. Recently a very hard vanadium steel made at the Bureau's laboratories has been tried and shows promise of success. More of it will be made, and if future experiments are successful, an important advance in the art of hardness testing may result.

Steel, Its Treatment and Products B3-23. QUENCHING EFFECT OF OIL-WATER EMULSIONS ON GAGE STEEL. Considerable time has recently been given at the Bureau of Standards to a study of the characteristic behavior of an oil-water emulsion (a mixture used commercially to some extent) as a quenching medium in the heat treatment of steels. It was found necessary to stir the mixture with high-pressure air to obtain a homogeneous emulsion in which condition it was very stiff and cooled the specimen much more slowly in the upper temperature range than oil. It had the peculiar property of cooling slowly half way and then very rapidly, the time to cool to one-tenth of the temperature range being about the same as for oil. This unique property is evidently due to entrapped air and should be studied further.

D—RESEARCH EQUIPMENT

The purpose of this section of Engineering Research is to give in concise form notes regarding the equipment of laboratories for mutual information and for the purpose of informing the profession of the equipment in various laboratories so that persons desiring special investigations may know where such work may be done.

Iron and Steel D1-23. ADDITIONAL FOUNDRY EQUIPMENT. Up to the present time, nearly all the work of the Bureau of Standards' foundry has been limited to the preparation of non-ferrous alloys. Recently the Bureau has purchased a small cupola to be used for investigational metal for castings used by the Bureau and other branches of the Government. During the past month, the construction of a charging platform and foundations for the cupola were completed. The installation and lining of the cupola are now in progress and the equipment will soon be ready for service.

CORRESPONDENCE

CONTRIBUTIONS to the Correspondence Department of MECHANICAL ENGINEERING are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities and policies of the Society in Research and Standardization.

The First Steam Locomotive Run on Rails in America

TO THE EDITOR:

In your issue for June, I notice on page 391 that you give a picture entitled "The *Stourbridge Lion*, The First Steam Locomotive Run on Rails in America." In the article accompanying this illustration you state, "The *Stourbridge Lion* was the first locomotive placed on any track outside of England, and the first that ever turned a wheel on the Western Hemisphere." In justice to the pioneer engineering work done by John Stevens I feel that it is no more than right to correct the impressions given by the quotations I have just made from your article.

In the year 1826, John Stevens constructed at his own expense a locomotive with a multitubular boiler which he operated for several years on a circular track on his estate at Hoboken. This track was laid in the level ground south of Castle Point and almost immediately in front of the site now occupied by Stevens Institute of Technology. A model of this locomotive with the original multitubular boiler is now preserved in the National Museum at Washington.

Not only was it three years after this achievement of John Stevens that the *Stourbridge Lion* was operated in this country, but it is to be noted as of no little importance to the credit of Mr. Stevens that his locomotive was designed and built by him in America, whereas the *Stourbridge Lion* was imported from England. An extended reference as to the accomplishment of John Stevens in building and operating what was really the first locomotive in America driven by steam and upon tracks is to be found in the addresses of J. Elfreth Watkins, at one time curator of the Section of Transportation and Engineering of the United States National Museum, before the Philosophical Society of Washington, May 7, 1892, and at the dedication of the monument erected by the Pennsylvania Railroad at Bordentown, N. J., November 12, 1892.

FRANKLIN DER. FURMAN.

Hoboken, N. J.

Boiler-Furnace Design

TO THE EDITOR:

The writer had the pleasure of being present at the meeting of the Metropolitan Section of The American Society of Mechanical Engineers when Edwin Ricketts presented his interesting paper on Boiler-Furnace Design, subsequently published in MECHANICAL ENGINEERING.[1] The following comments are made to discuss and interpret the facts in that part of the paper which deals with wall construction.

[1] Vol. 45, No. 5, May, 1923, pp. 299–304.

The importance of proper wall insulation and its effect in increasing boiler economy are clearly shown in Fig. 5 of Mr. Rickett's paper. The heat loss through the wall, which is composed of 9 in. of firebrick, $4^1/_2$ in. of insulating brick, and $8^1/_2$ in. of red brick with a furnace temperature of 2500 deg. fahr. is 310 B.t.u. per sq. ft. per hr. With the wall composed of $13^1/_2$ in. of firebrick and 9 in. of red brick, the heat loss with a furnace temperature of 2500 deg. fahr. is 776 B.t.u. per sq. ft. per hr. The saving due to insulation, therefore, is 776 − 310, or 466 B.t.u. per sq. ft. of boiler wall per hr. A computation will bring these savings down to dollars and cents.

For a boiler furnace 24 ft. wide, 20 ft. high, and 14 ft. long the total area through which heat radiates—side walls and front—equals 1040 sq. ft. Assuming further that the boiler in the case operates 300 days per year, 24 hours per day, on coal which has a heating value of 13,500 B.t.u. per lb. and is valued at \$6 per ton of 2000 lb. on the grate, with a boiler efficiency of 75 per cent the saving in B.t.u. per year equals 3,489,408,000; the saving in tons of coal will be 178.94 per annum, and the saving in dollars will be \$1073.64.

To insulate one square foot of surface $4^1/_2$ in. thick, 6.5 insulating brick would be required. The best insulating brick are $9 \times 4^1/_2 \times 2^1/_2$ in., standard firebrick size. A certain number of red brick

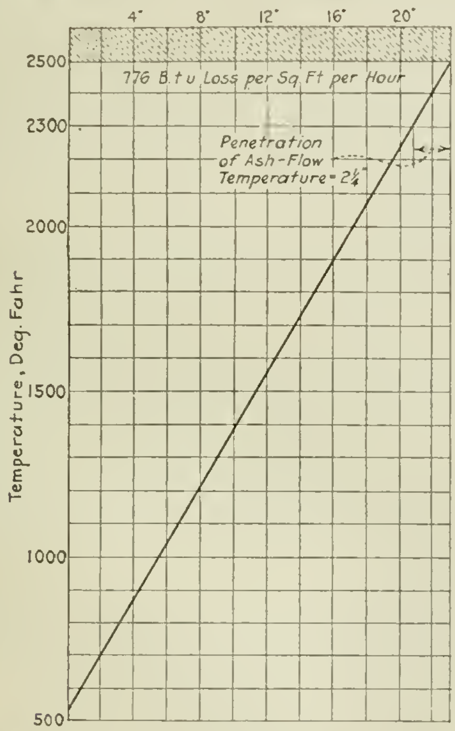


FIG. 1 TEMPERATURE GRADIENT THROUGH WALL COMPOSED OF FIREBRICK AND RED BRICK

will be displaced by the insulating brick—the red brick are usually about $8 \times 4 \times 2$ in.—and 8.5 brick will be displaced per square foot by the use of insulation.

Figuring the cost of insulating brick for the above area of 1040 sq. ft. at \$100 per M on the ground, the gross investment in insulation is $6750 \div 1000 \times \$100$ or \$675. The value of the same number of red brick displaced, together with the value of the additional red brick displaced and the labor required to lay the additional red brick, is as follows:

6750 red brick at \$20 per M with mortar	=	\$135.00
2100 red brick at \$45 per M with mortar and labor	=	94.50
		\$229.50

Deducting this amount from the gross investment leaves a net investment in insulation of \$445.50. The return of the net investment in insulation is therefore $(\$1073.64 \div \$445.50) \times 100 = 241$ per cent. Thus insulation of a boiler furnace is justified from a fuel-conservation standpoint alone.

Fig. 1 shows the temperature gradient through a wall composed of $13^1/_2$ in. of firebrick and 9 in. of red brick. The temperature gradient for firebrick and red brick is not in reality a straight line, but it may be considered so when used in connection with this discussion. The penetration of ash-flow temperatures is shown to be about $2^1/_4$ in.

Fig. 2 shows another wall composed of 9 in. of firebrick, $4^1/_2$ in. of insulating brick, and $8^1/_2$ in. of red brick. The temperature gradient through the insulated wall is shown in solid line. The dotted line is that for the temperature gradient through firebrick and red brick, from Fig. 1, which has been superimposed to facilitate comparison of temperature gradients. This shows plainly that there is an increase in temperature on the back of the firebrick of only 150 deg. fahr. due to insulation. The penetration of ash-

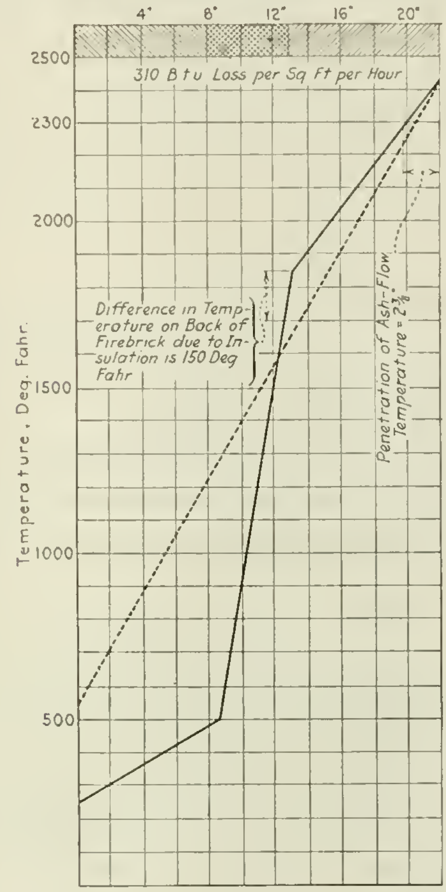


FIG. 2 TEMPERATURE GRADIENT THROUGH WALL COMPOSED OF FIREBRICK, RED BRICK, AND INSULATING BRICK

flow temperatures in the insulated walls is about $2^3/_8$ in. This is practically the same as that shown for the solid firebrick and red-brick construction.

But in actual practice the insulated wall, in spite of higher temperature at the back of the firebrick, would probably have a longer life of refractory lining because, with a given boiler producing a given amount of steam, the temperature in the insulated furnace will be less than the temperature in the uninsulated furnace.

Insulating brick can be easily installed between the firebrick and the red brick in brick-set boilers, or between the firebrick and steel casing in steel-encased boilers. The proper thickness of refractory lining should always be allowed as a protection for the insulating brick. With the insulated-wall construction and capacities as previously mentioned, it would be highly desirable to use an insulating brick which would withstand a temperature of 2000 to 2100 deg. fahr. without change in character or size.

Mr. Ricketts brings out the difficulties encountered when fireclay is used to lay up refractory lining in boilers operating at high capacities. But a good grade of high-temperature cement forms a definite bond between the firebrick and, if used, eliminates any danger of cracks which would allow the molten ash to get into the brickwork.

Based on this information the logical conclusion is that the ideal boiler wall is an insulated one, whether the boiler be brick-set or steel-encased. C. A. FRANKENHOFF.

East Orange, N. J.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

The American Society of Mechanical Engineers

29 West 39th Street, New York

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Warren Gamaliel Harding

By the untimely death of President Harding, the country has lost a kindly man who brought to the solution of many troublesome problems that lay in the wake of the war, the neighborly impulse for conciliation which will long keep his memory warm.

His Foreword to the F.A.E.S. Report on the Twelve-Hour Shift in American Industry and the pledge he drew from the iron and steel industry for the speedy elimination of the long-shift day are indelible evidences of the humanitarian principles which will mark him as one to whom posterity will be grateful.

The sorrow of the nation over the death of President Harding is profound and sincere. It is an expression of love and respect, and a recognition of great loss.

The Twelve-Hour Day

THE DEFINITE STEP taken by the United States Steel Corporation to abolish the twelve-hour day in continuous-process work is an outstanding recognition of the principle, supported by the late President Harding and general public opinion, that a "twelve-hour shift day is too long when measured by twentieth century ideas as to the proper conduct of industry." This action in the steel industry is of increased importance in that it points the way to the reduction of twelve-hour work in many other industries. The report issued last fall by the F.A.E.S. Committee on Continuous-Work Periods lists some forty industries in which 300,000 wage earners are on twelve-hour shifts. The long-shift workers in the steel industry number 150,000. Popular imagination has been excited by graphic pictures of heavy toil before fiery steel furnaces but the arduous twelve-hour periods in other continuous-process work is equally in opposition to modern ideas.

The change from the long day is a serious matter. No sudden, poorly conceived plan can bring permanent good to any industry and such a scheme may retard the consumation of desired results. Though hasty action in such an important matter should be avoided, immediate consideration of ways and means is important, so that at the proper moment a well-thought scheme may be put in use. The F.A.E.S. Report, referred to above should impress industrial engineers and executives with the immediate necessity for a study of the subject. It indeed contains many examples of the successful abolition of the twelve-hour day, sometimes with increase in economy and generally with an increase in the well-being of the workers and the industry.

The degree of success of the change from the twelve-hour day depends upon a great number of variables, differing in different industries and plants, but the critical conditions of a practical plan are "the readiness of the men to do more work in the shorter shift" and the acceptance of the management of responsibility of a high order to plan, supervise, and control so that the productive capacity of the men shall be steadily maintained during the shorter period. Much could be said on this point. Its importance is fundamental and there is evidence that the change to the three-shift basis stimulates improvements in management functions and in methods and equipment which go far toward balancing or may even overbalance, the increased labor cost anticipated by those who compute it upon a simple arithmetic basis.

Dean Kimball regards the abolition of the twelve-hour day as the acceptance of an industrial ideal which marks a distinct advance in economic progress. His views, given herewith, are of considerable interest.

"To students of industrial history the abolition of the twelve-hour day would seem to be a foregone conclusion. It is a relic of the dark ages of industry that are rapidly disappearing before a more enlightened understanding of the larger purposes of industry, and particularly of modern methods of production. These purposes in their essence are that men shall live more like human beings and less like animals. Otherwise, there is no worth-while achievement in labor-saving methods, labor-saving machinery and other means of increased production.

"The argument that such changes are not economically possible is the foremost argument that has been advanced against all such changes since the days of the Industrial Revolution. The entire history of modern industry shows that this argument is falacious. If any group of employers and employees have a real desire to shorten the length of their working period it can be done. Capital may have to be content temporarily with smaller profits, and labor may have to work more industriously, at least for the time being, but if those who are interested in such a movement in any industry see to it that no stone is left unturned within the industry itself that will aid in accomplishing this end, the public will gladly pay the difference in cost occasioned by a reasonable shortening of working hours.

As the editorial in this issue points out, any change of this kind in a large industry is a serious matter, not to be gone into precipitately, but if approached in an intelligent manner the change can surely be brought about. Without doubt the twelve-hour shift will disappear from American industry in a not far distant future."

A. P. Davis' Dismissal a Blow to Sound Government

"THE summary dismissal of Arthur Powell Davis from the directorship of the United States Reclamation Service is a vital blow to the cause of sound government and therefore a matter of grave concern to every responsible citizen. It demonstrates that even one of our highest national executives does not hesitate to evade Civil Service Law by a subterfuge, to terminate a lifetime of faithful, competent service for personal or political reasons and so to deter competent men from serving the nation, nor to accuse the entire engineering profession of business incompetence in the face of overwhelming evidence to the contrary even in the case in point.

It is imperative that all who demand honorable conduct of the nation's affairs, and particularly that all engineers shall vigorously resent the action of the Secretary of the Interior, and the motives he is reported to have given for it."

The foregoing statement by John Lyle Harrington, President of The American Society of Mechanical Engineers, is but one of a number of forceful protests against Mr. Davis' removal.

The Secretary of the Interior explained his action as a "simple incident of reorganization and the putting of a business man in

charge." Although having served the Government faithfully and well for over forty years Mr. Davis was denied a hearing to which he was entitled under Civil Service regulations on the grounds that the office of Director had been abolished. A former governor of Idaho, D. W. Davis, took over the work under the title of "Commissioner of Reclamation."

At its meeting in Chicago, July 10, the Board of Directors of the American Society of Civil Engineers issued a statement in protest of Secretary Work's action as follows:

The Reclamation Service has had an honorable and a creditable career of over twenty years. Its conduct during that period has been under the constant surveillance of the officers of the National Administration, of members of Congress and of the residents of the numerous committees in which the projects have been constructed.

The nature of its operations is such as to arouse the watchful care of those who are to be served and the active opposition of those whose interests might run counter.

Throughout this long period there has been no scandal and no sustained charge of lack of faithful loyalty to public interests. The works erected and the precedents established serve as worthy examples for our own country and have been used as a guide in such developments in other lands. The personnel of the Service has been remarkably loyal, conscientious and devoted to a high standard of public service. The dismissed Director has been either chief engineer or Director since the establishment of the work in 1902, and was at least entitled to a written statement of reasons for dismissal as provided in Civil Service regulations, and as required in proper administrative practice.

The reported reason of better administration advanced for the replacement of the Director by a successor under the new title of Commissioner, appears to be a pretext which is refuted by the long and honorable business record of the Director dismissed, in comparison with such record as we can obtain of the appointee selected to succeed him. The implication that engineers are not competent business administrators is refuted by numerous engineers who today are conducting as executives, many of the great railroad systems, public utilities and industrial enterprises of this and other countries, and the U. S. Reclamation Service is peculiarly an engineering enterprise.

The Board fears that any pretext of better administration could only be regarded as a perversion of the proper precepts of a rightful economy to suit the needs of an ever present political situation.

The Board deplores the action taken by the Secretary of the Interior, for the following reasons:

1 That it will work irreparable injury to the public service in the breakdown of morale and confidence of public employees

2 That it is an injustice to a man who has given forty-one years of faithful and valuable service to the Government of the United States

3 That arbitrary methods of removal are not creditable to a popular government based upon equality and fair dealing

4 That the change now inaugurated bears evidence of an attack upon a worthy and highly creditable branch of the government service to serve political needs

5 That the conversion of the Reclamation Service into a political machine would result in the withdrawal of public confidence and national financial support with the resultant injurious effect upon the development of the West.

The serious feature of Mr. Davis' dismissal is its discouraging effect on the large number of extremely capable engineers who are in the service of our Government. John R. Freeman, Past President of both The American Society of Mechanical Engineers and the American Society of Civil Engineers, in a letter addressed to Mr. Davis stated that "nothing recently has so shocked me as tending to the destruction of public service of high quality as the announcement of your dismissal after forty years of faithful service and a record of admirable efficiency." L. W. Wallace, Secretary of the American Engineering Council, wrote that "this incident will undermine the morale of all the technical agencies of the Government and may lead the most competent men to accept more readily engagements with commercial agencies, thus interfering with the efficient operation of the technical bureaus of the Government."

The Engineering News-Record emphasized the seriousness of the Davis incident and stated "that it may well be the beginning of a movement at Washington to make the government engineers merely the day-laborers of engineering work, the bosses of the concrete gangs, the instrument men of the surveys, the draftsmen and the estimators, leaving the direction of all of these to the so-called business man, who changes with each new administration or even with the political exigencies of the administration itself."

F. R. Low summed up the situation in a strong editorial in *Power*, an abstract of which follows:

"The hoped-for recognition of the importance of the engineer in governmental functions got a setback, when Arthur P. Davis was asked by Secretary Work of the Department of the Interior to hand in his resignation as Director of the Reclamation Service.

"Why was he put out?

"The reason given by the Secretary is that he wants to put a business man in charge. So he appoints a man who was a successful grocer, not so successful a banker, but a clever politician.

"And so we have the spectacle of one highly professional man—not a business man himself, by the way—a past president of the American Medical Society, dismissing another highly professional man, a past president of the American Society of Civil Engineers, to make room for a business man as "Commissioner" of a service that is largely one of civil engineering.

"If this kind of a thing is allowed to stand unchallenged, all the talk of putting the engineer to the front in the reconditioning of the country is as sounding brass and a tinkling cymbal."

The engineering profession and the public are entitled to the facts and aggressive steps should be taken promptly to reveal all of the details incidental to the dismissal of Mr. Davis. The ideals and functions of the engineering profession have been challenged.

Definition of Net Generator Output

THE Electrical Apparatus Committee of the American Institute of Electrical Engineers has outlined a set of definitions to be applied in determining the output of electric generators. These definitions have been divided into two principal parts, the first part covering measurements for station logging purposes where great accuracy is not necessary, while the second part covers test conditions where greater refinement is necessary.

This matter has been submitted to The American Society of Mechanical Engineers for comment.

The definitions as they now stand are given below, so that the membership will have an opportunity of criticising them. Any member having comments to offer will please address their communication to Herbert B. Reynolds, Secretary Power Division, 600 West 59th Street, New York City.

"For the purposes of station logging the generator output shall be considered to be the kilowatt-hours generated in a given period by the main unit.

"For purposes of efficiency determinations of the generators themselves or for purposes of comparison with other units this definition shall be modified in accordance with the following paragraphs:

1 In the case of a separately driven exciter, minus the power consumed in generator field and field rheostat.

2 In the case of a separately driven ventilating fan, minus the power input to the fan.

3 In the case of a direct-connected exciter, plus the kilowatt-hours generated by the exciter minus the power consumed in generator field and field rheostat.

4 In the case of a direct-connected auxiliary unit for supplying excitation and for power for turbine auxiliaries, plus the kilowatt-hours generated by the auxiliary unit, minus the power consumed in generator and auxiliary unit fields and field rheostats."

H. B. Reynolds,
Secretary Power Division A.S.M.E.

Errata

On page 473 of the August issue of Mechanical Engineering, in the paragraph on The Salt-Velocity Method of Measuring Flow (a part of the paper on Modern Hydraulic Turbines of Large Capacity, by H. G. Acres), the following words should have been omitted: "and uniform section" in the fifth line of the paragraph, "of uniform section" in the ninth and tenth lines, and "an instantaneous" in the fourteenth line.

On page 426 of the July issue of Mechanical Engineering in Mr. Toltz's discussion of Mr. Hood's paper on Lignite Char, reference is made to "lignite of 5400 B.t.u." This should read "lignite of 12,060 B.t.u." The lignite in question was mined at the Mine Ernst of the Anhalt Coal Co. in middle Germany and is called "raw brown coal."

Formulas for Computing Economies of Labor-Saving Equipment

Committee of A.S.M.E. Materials Handling Division Studies Problem of Evaluating Labor Saved by Improved Processes—Practical Application of the Formulas Devised

THE COMMITTEE appointed by the Executive Committee of the A.S.M.E. Materials Handling Division to consider and recommend rational formulas for computing the economic results, under stated conditions, of the installation of labor—conserving industrial equipment, has submitted the following report for consideration.

The problem presented is one of comparative costs. The tendencies in current practice which it is desired to correct are simply lack of consistency in treating the debit and credit items involved. Incidental items, such as interest on investment, taxes, maintenance, depreciation, obsolescence, etc., in other words, "fixed charges" or "burden," are currently accounted on the debit side when calculating the costs of substituting mechanical processes for manual ones. It seems, however, to have been unusual to make any contingent addition in calculating the monetary value of labor saved by improved methods.

In principle the desired formula represents simply a mathematical expression of such debit and credit items as are involved in the proposed new method, or process, as compared with previous practice. In highly organized and thoroughly systematized industrial practice, however, direct expenditures and direct economies are frequently of less importance in their monetary value than related incidental expenditures and economies. For instance, labor is employed in the factory for processing a raw material, which is thereby enhanced in value and becomes the factory's product. As a rule the total cost of the process will consist of, say, one part "direct labor" (labor which can be charged directly to a single process, or part of the product) and from one-half to three parts "fixed charge," "burden," or operating charge, consisting of "indirect labor" (labor which is of general utility and not chargeable directly), and such items as superintendence, employees' liability, welfare activities, maintenance of buildings and machinery, fuel, supplies, insurance, depreciation, taxes, accounting, etc.

The real problem in composing a formula, therefore, is not one of mathematics, but of economics. Not only should there be added to each dollar expended for improved equipment a suitable incidental amount (in percentage of the capital invested) to cover fixed charges or burden, but also a suitable incidental addition (in percentage) should be made to each dollar's worth of labor saved, as its proportion of "burden" saved. The extent of the expenditure for items accounted as burden will usually bear some fairly proportional relation to the amount of labor performed.

When calculating the cost of the finished product, if an improved process or equipment affects the amount and hence the cost of the "direct labor," then, for the most accurate results, the burden should be applied to labor *saved* at the same rate as labor *used.*

For the purpose of ascertaining the cost of the product, nonproductive labor, as a part of burden, should not be considered as subject to any contingent addition for burden. Yet for certain classes of accounting, particularly where comparative economies are being considered, non-productive labor may carry all items of burden that are chargeable to direct labor, except that it carries no contingent addition for its own class of indirect labor. It entails superintendence, employees' liability, welfare work, penalties for overtime and holidays, capital for payrolls, housing, heating and lighting, with the incidental maintenance, taxes, depreciation, and other charges, in the same way as direct labor.

Since a new process must of necessity be considered in comparison with an established process, no "burden" need be considered in respect to the labor used in either case, because the burden charge per unit of labor in one process will offset an equal unit of labor in the other process. The difference in labor required, however, must, in the interest of accuracy, be subject to its appropriate addition for "burden." For this class of cost accounting the cost department of an industry should ascertain the proper percentage to add for burden on both "productive" and "non-productive" labor.

Handling materials is practically always an important item of cost in manufacturing. With a complex product it would be difficult to charge handling costs to individual materials; and it is usually accounted as "non-productive" labor and distributed to various items of product, through an addition in the way of a percentage on direct labor, or an equivalent method, in common with other items of "burden." Here we have an example of labor expended in handling miscellaneous materials which would be accounted as "non-productive" labor.

If, however, we consider the employment of labor in transportation, in the handling of miscellaneous materials, it would naturally be accounted as "direct" labor, since it accomplishes an important and definite step in the process of transportation, and should therefore be subject to its pro rata share of all fixed charges whether it is labor used or labor saved by an improved process or by the substitution of mechanical process.

In the opinion of the committee, current practice which usually takes no account of "fixed charges" or "burden" on the excess of labor used by one process or on the labor saved by another process, represents a grave error in any analysis of comparative costs. Also in some cases where "burden" is added to "direct labor" in calculating comparative costs, it is omitted entirely where the labor is accounted as "non-productive," or indirect.

Based upon these considerations the following rule for setting a value upon labor saved by an improved process has been evolved:

> Whatever valuation is arrived at in cost accounting as the cost per unit of *labor used* in production, also establishes the value per unit of labor *saved* by an improved process. For simplicity, no monetary value need be placed upon labor employed in comparative processes, except upon the amount of *difference* in labor required at the current rate paid, plus "burden" or an equivalent.

Other items of cost should in like manner be accounted at the same rate as for similar items in making up the cost of product.

In calculating comparative cost a new item is introduced which never becomes a factor in regular cost accounting, namely, the monetary value of increased production. The profitableness of any industry stands or falls upon the relation between total cost of production and total volume, and hence value, of product.

An increase of product with a given equipment will affect the spread between cost and the market value of product just as vitally as an equivalent reduction in some or all of the items of cost. Accordingly, no system of comparative cost accounting can pretend to even approximate accuracy which does not place a suitable valuation upon increased productivity.

In placing a valuation upon increased productivity it should be borne in mind that in any industry the volume of product required to just meet the costs of the plant and a given organization affords *no profit;* also that any product above that amount is obtained without any manufacturing cost whatever; hence the rule:

> In a comparative accounting increased production will always carry a higher value than that attached to normal production.

The Committee therefore unanimously recommends the following methods:

Let:

Debit Items:

A = percentage allowance on investment
B = percentage allowance to provide for insurance, taxes, etc.
C = percentage allowance to provide for upkeep
D = percentage allowance to provide for depreciation and obsolescence
E = yearly cost of power, supplies, and other items which are consumed, total in dollars

Credit Items:

S = yearly saving in direct cost of labor in dollars
T = yearly saving in fixed charges, operating charges or burden, in dollars
U = yearly saving or earning through increased production, in dollars

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Presented at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS.

X = percentage of year during which equipment will be employed

I = initial cost of mechanical equipment

Results
- Z = maximum investment in dollars justified by the above consideration,
- Y = yearly cost to maintain mechanical equipment ready for operation
- V = yearly profit from operation of mechanical equipment.

Then

$$Z = \frac{(S + T + U - E)X}{A + B + C + D} \qquad [1]$$

$$Y = I(A + B + C + D) \qquad [2]$$

and

$$V = [(S + T + U - E)X] - Y \qquad [3]$$

Feeling that handling machinery, even if left idle a large part of the year, would probably require, under most conditions, approximately the same repair through deterioration as though in use, the Committee makes no deduction for such lack of use in the estimated cost of upkeep C. If greater accuracy be considered necessary, use C multiplied by X in place of C in the formulas.

Applications of the Formulas

As an example of an application of the formulas, assume that the handling of miscellaneous materials about a factory which has formerly been done by four men receiving \$3.50 per day each, or, allowing 300 days per year, at an annual direct cost of \$4200, can be done by one man operating an electric storage-battery industrial truck at a direct-labor cost of \$1050 per year, thus effecting a saving at the rate of \$3150 per year in direct-labor cost.

Assume also that through the greater promptness in moving materials and the more continuous operation of machines there is an increase in earnings, due to increased production, valued at \$650 per year; also that the labor involved, being accounted as "non-productive," carries a fixed charge or burden of 10 per cent. In actual practice the plant operates 240 days per year or 80 per cent of the time. The various factors therefore, are estimated as follows:

A = 6 per cent	S = \$3150
B = 4 per cent	T = 315
C = 20 per cent	U = 650
D = 25 per cent	X = 80 per cent
E = \$450	

$$Z = \frac{(\$3150 + \$315 + \$650 - \$450) \times 80}{55} = \$5331.$$

This indicates that equipment costing any sum below \$5331 will earn some profit above interest on investment and maintenance.

Assume that an electric storage-battery industrial truck will meet the conditions stated and that its cost will be \$2200. Then the yearly cost to maintain equipment ready for operation, exclusive of labor, will be expressed by the formula, $Y = I(A + B + C + D)$ or \$2200 × 55 per cent = \$1210. Then the profit from operation of the mechanical equipment, according to [3], becomes (\$3150 + \$315 + \$650 — \$450) × 0.80 — \$1210 = \$1722.

The profit V, or \$1722, represents an annual earning upon the initial investment, over all items of cost, of over 78 per cent.

If, however, our example be applied to handling cargo at a railroad or marine terminal where the labor is *productive labor* and subject to *all* fixed charges as burden, an important difference in result will be had, indicating the importance of the factors T and U, and the necessity of placing proper values upon them if reliable results are to be had.

As such an example of an application of the formulas, assume that in handling miscellaneous cargo at a marine terminal, work which has formerly been done by four men receiving \$3.50 per day each, or, allowing 300 days per year, at an annual direct cost of \$4200, can be done by one man operating an electric storage-battery industrial truck at a direct-labor cost of \$1050 per year, thus effecting a saving of \$3150 per year in direct-labor cost.

Since this labor is productive labor, it will bear its pro rata share of all fixed charges, estimated at 50 per cent and to be added to the direct-labor cost, representing a further saving of \$1575 on account of labor. Also that, through the greater promptness in unloading and loading vessels, 5 per cent more ships can be accommodated, accounting for 15 days' extra use of the pier yearly. Assuming the investment in the pier to be \$1,000,000 and interest, taxes, etc., at 10 per cent, we have a credit item of 0.5 per cent to be divided, say, between 20 electric trucks, or \$250 per truck per annum.

Applying the formulas as in the previous example, we have

$$Z = \frac{(\$3150 + \$1575 + \$250 - \$450) \times 80}{55}$$

= \$6582 permissible investment.

The yearly cost of operation is Y = \$2200 × 0.55 = \$1210 as in the previous example. The profit above maintenance charges, V, will then be (\$3150 + \$1575 + \$250 — \$450) × 0.80 — \$1210 = \$2410.

The profit \$2410 represents an annual earning of nearly 110 per cent upon the investment in this case in place of 78 per cent in the previous example, all factors having been upon exactly the same basis except T (yearly saving in fixed charges) and U (yearly saving through increased production).

The following summary shows the relative value of the same device applied to two conditions, first, where the labor employed in the work is unproductive as regards producing an article of manufacture, and, second, where the labor used produces the salable commodity, in this case material handling.

	Case 1 Handling in Factory	Case 2 Handling in Marine Terminal
Cost of equipment	\$2200	\$2200
Z, investment justified	5331	6582
Y, yearly maintenance	1210	1210
V, profit from installation	1722	2410
Per cent return on investment	78	110

A study of this comparison indicates that with suitable values given to the factors the formulas proposed show not only the advantages obtainable under various conditions, but also that a device may be much more valuable per dollar invested in one industry than in another. The difference shown would have been much more pronounced had regular stevedores' wages been used for the wages of the man at the marine terminal.

The personnel of the committee which prepared this report consisted of W. F. Hunt, consulting engineer, New York, J. A. Shepard, of the Shepard Electric Crane & Hoist Co., Montour Falls, N. Y., and C. H. Newman, New York.

Stationary Steam-Generating Units

(Continued from page 558)

		B.t.u.	Per cent
(97)	Efficiency of economizer	....	....
	Air Heater		
(98)	Heat available to air heater in flue gases including moisture, T_7 to T_2	....	....
(99)	Heat absorbed by air heater	....	....
(100)	Efficiency of air heater	....	....

Note—If unit does not include economizer do not fill out Items 87, 93, 96 and 97. If data are available for further segregation of losses, other items may be added.

Table 12*d* Heat-Balance Computations for Steam-Generating Unit Comprising Boiler, Superheater, Economizer, and Air Heater. Gaseous Fuels

Item

(84) = *Item* 33

(85) = *Item* 78×970.4

(86) = $(H_1 - H) \times$ *Item* 77

(87) = $(h - h_1) \times$ *Item* 77

(88) = $\frac{CO}{CO_2 + CO} \times C \times 10160$

(89) = *Item* 43 × $(T_8 - T_2) \times 0.24$*

(90) = $(1090.7 + 0.455\ T_8 - T_{12}) \times \left(\frac{\textit{Item } 21 + 9 \times \textit{Item } 23}{100}\right) + (\textit{Item } 43 - C) \times \textit{Item } 45 \times 0.455 \times (T_8 - T_2)$

(91) = (*Item* 39 − *Item* 43) × $(T_8 - T_2)$ × (0.24 + *Item* 45 × 0.455)

(92) = (*Item* 40 − *Item* 39) × $(T_8 - T_1)$ × (0.24 + *Item* 45 × 0.455)

(93) = (*Item* 41 − *Item* 40) × $(T_8 - T_1)$ × (0.24 + *Item* 45 × 0.455)

(94) = (*Item* 42 − *Item* 41) × $(T_8 - T_1)$ × (0.24 + *Item* 45 × 0.455)

(95) = *Item* 84 − Sum of *Items* 85, 87 to 94, inclusive, and *Item* 99

(96) = $(T_6 - T_{10}) \times \left\{\textit{Item } 40 \times 0.24 + \left[(\textit{Item } 40 - C) \times \textit{Item } 45 + \frac{\textit{Item } 21 + 9 \times \textit{Item } 23}{100}\right] \times 0.455\right\}$

(97) = $\frac{\textit{Item } 87}{\textit{Item } 96}$

(98) = $(T_7 - T_2) \times \left\{\textit{Item } 41 \times 0.24 + \left[(\textit{Item } 41 - C) \times \textit{Item } 45 + \frac{\textit{Item } 21 + 9 \times \textit{Item } 23}{100}\right] \times 0.455\right\}$

(99) = $(T_3 - T_2) \times$ *Item* 44 × (0.24 + *Item* 45 × 0.455)

(100) = $\frac{\textit{Item } 99}{\textit{Item } 98}$

* Note—*Items* 89, 91, 92, 93, 94, 95, 96 and 98. 0.24 is the value in common use for the specific heat of dry gases. This value is not exactly correct and if extreme accuracy is desired the true specific heat should be calculated from the gas analysis.

Note—*Items* 90, 91, 92, 93, 94, 95, 96, 98 and 99. These formulas are correct only when the total moisture in the gases is less than that necessary to saturate the gases of the final temperatures indicated. If the relation of moisture and temperature is such that some moisture will be condensed, these items should be corrected for the heat given up by the condensing vapor.

Engineering and Industrial Standardization

Recent Progress in Standardization of Particular Interest to Mechanical Engineers

A.E.S.C. Considers Specifications for Cast-Iron Pipes. The American Gas Association has submitted for the approval of the American Engineering Standards Committee three specifications for cast-iron pipe and special castings.

These specifications were developed by the American Gas Institute in 1911, at which time the dimensions for bell-and-spigot castings were adopted. In 1913 the Association adopted the dimensions for flanged castings, and specifications governing the manufacture of all cast-iron pipe and specials, which were derived from an old standard adopted in 1905 by the American Gas Light Association. These again were based on seven years experience with the standards designed by the Society of Gas Lighting in 1890. It is said that the specifications now under consideration are in general use for underground gas pipes throughout the U. S.

The A.E.S.C. has appointed a large and thoroughly representative special committee to consider the application for the approval of these specifications, and sponsorship for future revisions under the regular procedure involving the organization of a representative sectional committee to consider and develop any changes required. S. G. Flagg, Jr., one of the representatives of The American Society of Mechanical Engineers on A.E.S.C., is chairman of this committee. He will be glad to receive at his address, S. G. Flagg and Company, 1421 Chestnut Street, Philadelphia, Pa., suggestions relative to the approval of the A.G.A. Standards and to the standardization of cast-iron pipe and fittings in general.

Overhead-Line-Material Specifications. The American Electric Railway Association has submitted its specifications for overhead-line material for action by the A.E.S.C., to determine the question of sponsorship and to arrange for the submission of the specifications already developed by the A.E.R.A. to a duly organized sectional or working committee, which will make such revisions and additions as may be necessary to bring these specifications up to the full status of an "American Standard." The special committee to consider the question of sponsorship and scope of the specifications, which are also of direct interest to other than electric-railway interests, is headed by A. H. Moore, representing the Electrical Manufacturers' Council on the A.E.S.C., and includes representation from the National Electric Light Association, American Railway Association, Electrical Manufacturers' Council, American Institute of Electrical Engineers, American Electric Railway Association, American Short Line Railway Association, and the Bell Telephone System.

The attitude of the A.E.R.A. in submitting its specifications for this action by the A.E.S.C. will very definitely favor the unification and elimination of conflicting specifications in this field, which is a very important one to a large group of industries and involves expenditures of great magnitude annually in construction, maintenance and replacement of power, light, telephone, telegraph, and railway signal lines.

Test Methods for Materials for Concrete Approved. The following A.S.T.M. methods of testing materials entering into concrete have been approved as "Tentative American Standards" by the American Engineering Standards Committee:

Method of Test for Unit Weight of Aggregate for Concrete
Method of Test for Voids in Fine Aggregate for Concrete
Method of Test for Organic Impurities in Sands for Concrete

The method of determining the impurities in sands had its origin in an investigation, begun in 1916, of a variety of concrete mixtures with different sizes and gradings of granite. The test, as a method, has proved itself useful for prospecting for sand supplies, preliminary examination of sands in the laboratory, and checking the cleanness of sands on the job.

The method for determining unit weight is the result of a very considerable amount of coöperative investigational work in which seven laboratories participated. The investigation shows that the particular method adopted gave more reproducible results than other methods; it was found in practice to be simple and commercially satisfactory and to furnish an easy basis for the computation of the percentage of voids.

In approving these standards the A.E.S.C. acted upon the recommendation of a special committee containing representatives of twelve interested organizations and under the chairmanship of Mr. T. H. McDonald, Chief of the Bureau of Public Roads.

The American Society for Testing Materials will act as sponsor for future revisions of these test methods.

Railway-Bridge Specifications. Specifications of interest to the railway and structural-engineering fields have recently been submitted by the American Railway Engineering Association for approval by the American Engineering Standards Committee as American Standards. They are as follows:

General Specifications for Steel Railway Bridges for Fixed Spans Less Than 300 Feet in Length, 1920, revised to May, 1923.

Specifications for Movable Railway Bridges, 1922.

A large special committee will be appointed by the A.E.S.C. to determine whether these specifications are suitable for adoption as national standards in this country. All the principal organizations interested in these two subjects will be invited to appoint representatives on this special committee.

In submitting the specifications the A.R.E.A. states that "the General Specifications for Steel Railway Bridges and the Specifications for Movable Railway Bridges were prepared by Committee XV on Iron and Steel Structures, of the American Railway Engineering Association. This is a standing committee and it has prepared all specifications for steel bridges adopted by the Association."

The A.E.S.C. would be very glad to learn from those interested of the extent to which these specifications are considered to meet the requirements of bridge-building practice and railway service.

Dictionary of Specifications. For the purpose of bringing about the general use of specifications as the basis for the purchase of supplies by the federal, state and municipal governments and public institutions, plans are now being inaugurated by the Department of Commerce for collecting into one dictionary or encyclopedia such specifications as have proved most satisfactory for this purpose.

In this dictionary will be included not only the specifications formulated under the Rules of Procedure of the American Engineering Standards Committee and those developed by the Federal Specifications Board, but all other specifications known to be satisfactory for the purchase of commodities not as yet covered by the specifications of the Board.

In selecting specifications for inclusion in the dictionary due consideration will be given to the attitude of the producers and consumers of the commodities toward them. In addition, federal, state and municipal governments and public institutions will be consulted. A comparison will be made between Government specifications and specifications for the same commodities formulated by well-established organizations of producers and consumers.

Dr. A. S. McAllister, engineer physicist, Bureau of Standards, who during the past two years has been liaison officer of the U. S. Bureau of Standards and the Federal Specifications Board, assigned to the headquarters of the American Engineering Standards Committee at New York, has been recalled to Washington by Secretary Hoover for this special work. He will welcome suggestions and data which will assist him in making the first edition of this volume as complete as possible.

Standardization of Railroad Ties. The personnel of the Sectional Committee for the Standardization of Railroad Ties is now announced by the American Engineering Standards Committee. Mr. John Foley, connected with the Pennsylvania System at Philadelphia and the representative of the American Railway Electric Association on the Committee is its chairman, and Mr. Arthur T. Upson, the representative of the U. S. Forest Service, has been elected secretary. Mr. Upson's address is care of the Forest Products Laboratory, Madison, Wis.

At present the Committee is made up of representatives of 15 organizations. Of its 16 members, 7 are classed as producers, 5 as consumers, and 4 as general interests.

LIBRARY NOTES AND BOOK REVIEWS

Kent's Mechanical Engineers' Handbook

Kent's Mechanical Engineers' Handbook. By the late William Kent, M.E., Sc.D. Tenth edition rewritten by Rorbert Thurston Kent, M.E., editor-in-chief, and a staff of specialists. Leather and atholeather, $4\frac{1}{2} \times 7$ in., profusely illustrated, $7; $6.

[The issue of a mechanical engineer's handbook is an interesting event to the entire profession. We are able to present reviews of the new "Kent" by Dr. Arthur M. Greene, Jr. and R. J. S. Pigott. Editor.]

The tenth edition of Kent's Mechanical Engineers' Handbook, written originally by the late Wm. Kent, is rewritten by his son Robert Thurston Kent, M.E., and a staff of specialists. This new feature of having associates reponsible for definite parts of the work has greatly increased the value of this well-known reference book and gives it even more authority than it had in the previous editions.

Although the general subjects discussed in this new edition are about the same as in the former editions, the arrangement of the matter is changed greatly and the present form is much more convenient than that used previously. The plans of having each of the twenty-six sections of the book begin with a table of contents of the section, with its subdivisions, and having a bibliography in each section or subdivision, are both commendable. These will be very helpful to the users of the book.

The book has been brought up to date in many places, some references being made to articles appearing in the early part of 1923. Although many references to modern practice have been brought up to date it is to be regretted that in parts of the book old data have not been entirely eliminated. The section on steam boilers does not contain data on operation of certain stokers of the chain-grate type which should be in the hands of engineers. The form of modern firebox even with underfeed stokers on large boilers of the Stirling type is not mentioned. The same is true in a few other places.

This book like the "Kent Bible" of the nineties is fitted to answer most of the questions the mechanical engineer may ask in the operation of a plant he is laying out or managing. If he wants to know how large a turbo-generator has been operated and tested he can turn to the most excellent section on the steam turbine and get water rates and other data. By the method used in this section by Prof. A. G. Christie, its author, he can compare probable water rates under other operating conditions and find the total steam needed. The section on materials will give dimensions of pipe fittings, valves, and bends after the size of the pipe is fixed from the data on steam flow found in Section XIII. This section will give data regarding feedwater, heaters, economizers, condensers and other auxiliaries. If sizes of parts are to be investigated, this section and Section XVIII on machine design will give the necessary formulas and tests.

The strength of various beams and columns, the dimension sheets of cranes, the sections on lighting, heating and ventilation, and electrical engineering are all available to complete the design of the power house, while Section XXII on buildings will give data regarding foundations, walls, and reinforced-concrete and framed structures.

For general manufacturing the sections on power transmission, transportation, hoisting and conveying, friction, and lubrication will be of particular value. The section on power transmission has been rearranged by Mr. Kent and is much more helpful than it was in the earlier editions. The section on transportation is most excellent, dealing with locomotives, automobiles, and airplanes. The section on hoisting and conveying is well presented and gives data for all kinds of material-handling apparatus.

For shop work in manufacturing, for refrigeration, and for safety engineering as well as for marine engineering, sections are provided and the plant manager or designer can turn to these for most all of the data he may need in his work.

The matter dealing with materials is now arranged in such a manner that data relating to definite groups of materials are brought together in sections. General data are given in Section III on materials, with certain information regarding weights, safe loads, sizes, and tables of standards. Section IV is on strength of materials and contains much data from tests. Section V is an excellent one by Bradley Stoughton on iron and steel, while Section VI is on the non-ferrous metals and alloys. It is not easy to understand why certain data regarding cast iron and malleable iron were not placed in Section V in place of Section XX on shop practice.

Section IX on air includes data regarding the compression of air and its subsequent transmission. The data on fans and blowers are quite complete.

For those installing hydraulic apparatus, Section X on water hydraulics and water power and Section XI on pumps and pumping engines will be of interest. Mr. R. E. B. Sharp who has written the section on Hydraulic turbines has brought it up to the latest developments and this is true of all of the associates in their respective sections.

Section XII on fuels and combustion contains numerous tables of fuel data and also methods of calculating actions which may take place within furnaces.

The work has been increased in size from about fifteen hundred pages to almost twenty-three hundred pages. Much of this is due to new tabular data and to figures showing apparatus and curves giving test relations. Many figures of machine parts are shown to aid the designer as well as dimension and clearance sheets to give information for preliminary layouts. Some of the increase is due to the addition of test material in the various sections to make them of greater value.

In going over the text certain omissions have been noticed which are regretted by one who would like to see an all-inclusive book. The absence of any data regarding hyperbolic functions, spherical trigonometry, the use of semi-log paper, Rankine's methods of rectifying arcs, the strain formula of combined stress, and of modern data on flat plates was noted in this hasty review. Of course the editor of such a work must decide what is to be included and what is to be omitted, and the reviewer can only say that he wishes these things were in the book.

The book appeals and will be welcomed by the profession as a valuable adjunct to the books used at present.

Arthur M. Greene, Jr.[1]

The new edition of Kent's Handbook shows evidence of a great deal of painstaking work in the thorough revision that has been carried out. In the materials section the information on refractories and acid-resisting materials is useful, although it could probably be enlarged.

The extensive tables that have been one of the strong features of this handbook are still further enlarged. The treatment of much of the strength-of-materials section is new and excellent; the section on iron and steel is also very well done and has been given a much needed extension over the earlier material. The material on deaeration gives a good, though brief, expression of the present knowledge on the subject.

The section on non-ferrous metals and alloys contains considerable material that is simply unknown to the average engineer and is very hard to obtain, as but little real material is published on the subject. We certainly need more information generally on the behavior and properties of non-ferrous materials under high working temperatures.

In the section on heat, the transmission of heat in boilers and condensers is carried as far as the present chaotic mass of data will permit. The work of George A. Orrok on condenser tubes seems to be one of the very few attempts made to arrive at rational solution. The heat-insulation section is extended and well done.

The compressed-air section is full enough in treatment to be very useful; usually this subject is so badly underhandled as to be nearly

[1] Dean, School of Engineering, Princeton University, Princeton, N. J. Mem. A.S.M.E.

useless. The use of Mr. Hagen's curves for fan capacities is commendable since this form of arranging performance data is about the most useful that has yet been devised. It would be a boon if all the manufacturers would use this form of curve, as it comes close to removing most of the mystery from the time-honored methods of treating fan performance, so that an *average* engineer can pick out the right blower.

The treatment of hydraulic turbines is much improved, and the free use of characteristic diagrams is of advantage. The material on centrifugal pumps immediately following gives a clearer idea of the similarity in the general theory.

The material on pulverized fuel, which occupies the center of the stage just at present, is necessarily very brief; the art is in such a stage of rapid, almost violent, development, that it is unsafe to attempt to tie down facts just now. Even the builders themselves are not sure of much.

The boiler and stoker material has been entirely rewritten, and at last the hand fire has been relegated to the place it belongs—obscurity. The treatment of performance from the point of view of the elder Kent's formula is interesting, although the writer personally prefers analysis on the basis of the input-output line, together with Lucke's method of analyzing heating surface and furnace efficiency.

The turbine section is exceptionally good; the difficult subject of stresses and critical speeds, and test data, is worthy of particular notice. The increasing use of thermal and Rankine efficiencies as a means of comparison instead of water rates has now become firmly established, and is largely used in this section.

The handbook as revised, contains an unusually large collection of tabular data, and should easily renew its long, continued popularity. Handbook arrangement is largely a matter of taste; two other methods have been employed in the writing of similar handbooks, but there is little difference in use, provided the indexing is good. The writer hopes that hand book publishers will one day have the courage to abandon the abominable little fat volume and adopt the 9 in. by 12 in. desk-book size that Fred Halsey employed for his Machine Designers Handbook. No one ever tries to carry a so-called pocket book in his pocket and the larger size gives opportunity for a much better scale of charts.

R. J. S. Pigott.[1]

The Life of Yarrow

Alfred Yarrow His Life and Work. Complied by Eleanor C. Barnes (Lady Yarrow). Longmans, Greene & Co., New York; Edward Arnold & Co., London, 1923. Cloth, 6 × 9 in., 328 pp., illus., $3.50.

The life of Yarrow is a welcome addition to the too short list of inspiring biographical works about engineers of great character. Alfred Yarrow was great in that his outstanding mechanical ability did not outshine his sweetness of soul and the story of his life, simply and sympathetically told by Lady Yarrow, should be in every technical library.

As a schoolboy, Yarrow, bright, quiet and lovable, was proficient in mathematics and physics. He showed his mechanical genius at an early age in devices to perform some of his irksome houshold duties. While serving his apprenticeship, which demanded early rising, he constructed an arrangement which lighted the fire in his mother's room and in his own room ten minutes before the alarm clock sounded.

He attended all the scientific lectures that he could and, becoming interested in the telegraph, erected the first private telegraph line to London, crossing several properties and two public roads. The overcoming of popular objections to this line brought out the characteristics that seemed to underlie Yarrow's future success, for he later pointed out that the mechanical part of an enterprise frequently gives less trouble than the diplomatic side, and that "to show patience, courtesy, tact and, in the end, to obtain what is desired whilst remaining on friendly terms with all concerned—is the real art of business."

Toward the close of this apprenticeship, Yarrow designed a successful scheme of steam plowing. Steam plowing, however, was not suited to English conditions and his royalties were not large. Then he turned his attention to a steam carriage, but his activities were halted by the passage of a bill forbidding the use of steam on a road unless the carriage were preceded by a man carrying a flag.

[1] Mech. Engr., Stevens & Wood, New York, N. Y. Mem. A.S.M.E.

Yarrow with a partner established his modest shops and after many vicissitudes built a steam launch which was successful. Thus he became established in marine work. His successes came fast upon each other from then on and his workmanship and design were in great demand for high-speed boats of all kinds. His ingenuity and resources were sought by many individuals and governments. Stanley sought his help to navigate the Congo; the British Government wanted boats to relieve Gordon at Khartum, and later he supplied torpedo boats. In the great war, destroyers were his principle contributions and valuable ones they were. Yarrow's life and work is a story of marine development over an exceedingly important period.

Book Notes

Applied Personnel Procedure. By Frank E. Weakly. McGraw-Hill Book Co., New York and London, 1923. Cloth, 6 × 8 in., 192 pp., $2.

This book is not intended to be an exhaustive treatise on personnel administration, but rather to describe in concrete fashion a number of phases of personnel management with which the work of the author has made him familiar. He writes from long experience as a worker, as head of a personnel department, and as a general executive. The methods that he describes will fit both large and small organizations and have been tested by use.

Aufoabensammlung Zur Festigkeitslehre. By R. Haren. Walter de Gruyter & Co., Berlin and Leipzig, 1923. Boards, 4 × 6 in., 116 pp., diagrams, tables, $0.25.

In a volume of convenient pocket size and of small cost the author has collected sixty-six problems relating to the strength of materials, which he presents with complete solutions. The problems are those that occur frequently in machine design.

Automobile Shop Practice. By Edward K. Hammond and F. D. Jones. Industrial Press, New York, 1923. Cloth, 6 × 9 in., 306 pp., illus., $3.

This treatise takes up the manufacture of automobiles as carried on in this country, and describes the standards and special tools, machines, and processes used in many plants. The parts selected for description are those which require unusual tools and processes to obtain accurate work and large output. The authors believe the book will be of interest to those engaged in similar classes of work in other lines.

Automatic Sprinkler Protection. Supplement to second edition. By Gorham Dana. John Wiley & Sons, New York, 1923. Paper, 5 × 8 in., 40 pp., illus., $0.50.

A supplement to the 1919 edition of the author's book. Includes descriptions of new devices that have been introduced since that date, as well as several soon to be introduced.

Dictionary of Applied Physics, vol. 4; Light, Sound, Radiology. By Richard Glazebrook. Macmillan & Co., London, 1923. Cloth, 6 × 9 in., 914 pp., illus., diagrams, tables, 63s.

Volume four of this dictionary follows the plan of its predecessors, that is, it defines briefly the minor terms in its field and refers the user for further information to the extended articles by experts on general topics. These general articles are well-rounded summaries of present knowledge on the principal topics, provided with adequate references to the literature.

In this volume the subjects discussed are sound, light, and radiology. Special articles are included on crystallography, diffraction grating, the eye, glass, goniometry, graticules, infra-red transmission, interferometers, the kinematograph, lenses, light, luminous compounds, the microscope, navigational instruments, opthalmic apparatus, optical calculations, optical glass, periscopes, photographic apparatus, photometry, the pianoforte, polarimetry, polarized light, projection apparatus, the quantum theory, radiation, radioactivity, radiology, radium, range finders, shutters, sound, sound ranging, spectrophotometry, spectroscopes, spherometry, surveying instruments, telescopes, and wave-length measurements.

Diesel and Oil Engine Handbook. By Julius Rosbloom. Technical Publishing Co., Los Angeles, 1923. Boards, 5 × 7 in., 376 pp., illus., diagrams, tables, $3.

The first five chapters of this handbook explain the principles of the Diesel engine, describe the pumps, governors and other auxiliary machinery, and give directions for testing. Chapter six offers detailed descriptions of a number of commercial types, and chapter seven discusses Diesel-electric ship propulsion. The book is intended as a reference work for practical men.

The Dynamo, Its Theory, Design and Manufacture. Vol. 2. By C. C. Hawkins. Sixth edition. Isaac Pitman & Sons, New York and London, 1923. Cloth, 6 × 9 in., 322 pp., illus., diagrams, 15s.

In the opening chapter of this volume, which completes the study of continuous-current dynamos, a detailed analysis of the effect of armature reaction on the flux curve under load is given both for non-commutating-pole and commutating-pole machines. Succeeding chapters discuss commutation and sparking at the brushes, the heating of dynamos, dynamo design, working, and management. Two designs are worked out in full, to illustrate the application of the numerous formulas which have been given in the text.

Electric Motors; vol. 2, Polyphase Current. By Henry M. Hobart. Third edition. Isaac Pitman & Sons, London and New York, 1923. Cloth, 6 × 9 in., 384 pp., diagrams, $4.50.

Volume one of this treatise was reviewed recently. The concluding volume continues the account without interruption, giving special consideration to polyphase-current questions. The treatise is intended for the designer rather than for the student and is intended to show the state of the art at the present time.

Motor Fuels, Their Production and Technology. By Eugene H. Leslie. Chemical Catalog Co., New York, 1923. Cloth, 6 × 9 in., 681 pp., illus., diagrams, tables, $7.

An encyclopedic book on motor fuels. Dr. Leslie has not confined himself to the technology of the subject, but has included material of an economic nature and has made the contents of his book miscellaneous in some measure, so that it is of interest to the general reader as well as the student and the refinery engineer.

A special effort is made to present accurately the fundamental principles of physics, thermodynamics, and chemistry underlying the operations used in producing motor fuels, and also to review the research work in several fields where present knowledge is still unsatisfactory. Numerous bibliographies and tables are given.

Material-Handling Problems in Pier Design

(*Continued from page 530*)

time. The cost of getting things into and out of a car now was an enormous tax.

The author, in closing, said that as far as the stevedore question was concerned, he thought it was generally conceded that Philadelphia had about the highest grade of stevedores on the Atlantic coast. When it came to the question of installing machinery in pier sheds, the harbor authorities in the United States would hesitate a long while before doing so because usually such equipment was in the hands of the pier operators, who were generally careless in their use of publicly owned equipment. If some of the harbor authorities in the states actually operated the piers, as did one or two on the West Coast, he thought it would result in a greater extension in the use of mechanical equipment.

American dock authorities had hesitated in putting in pier machinery because of some doubt as to its efficiency and because they did not care to leave it in the hands of the operators.

The question of the two-decked pier had been raised by Mr. Birch. The cargo from the second deck was easily shifted to the first deck through gravity steel tubes. There was one pier in Philadelphia, owned by the Philadelphia and Reading Railway, which had second-deck tracks, and any two-deck pier which could be provided with tracks on the second deck would have a tremendous advantage over one not so equipped. Car elevators and also traveling cranes inside the pier shed had been considered, but the question of leaving that equipment in the hands of pier operators seemed to be a stumbling block, particularly with the harbor board that was not equipped properly with its own facilities, so to his mind the whole question simmered down to the desirability of a harbor board.

Determination of Chimney Sizes

(*Continued from page 537*)

In his closure, the author said that he believed that Professor Smallwood had overlooked one or two points set forth in the paper. It was obvious that the maximum capacity being independent of the height was based upon having the same conditions in all cases, including the mean temperature of the gases. If comparison was being made of two actual or proposed chimneys of different heights, the appropriate mean temperatures would be found as directed, so that this point was fully taken care of in the paper.

Leakage of air at breechings did not impair the method presented in the paper because the designer must naturally base his calculations on the weight of gases going up the chimney.

No one deplored more than the author the lack of information on chimney performance, or would more heartily welcome exhaustive research. However, Professor Smallwood would see on further consideration, that the method was not based on the slender support of the meager information now available but simply utilized what knowledge was so far available. As shown in the paper, further research would enable more accurate results to be attained by the use of the method. But to impugn the method because of lack of authoritative data was like suggesting that we discontinue the use of the micrometer until we have decided whether the inch or the meter is the better unit with which to graduate it.

In preparing the curves for finding mean temperature, the curve of temperature drop No. 1 in the Appendix was given the greatest weight since it was the only one in which the weight of gases was even approximately known. As the weight of gases in the Johns Hopkins tests was not given, no considerable use could be made of them except in a very general way.

Mr. Marsh had drawn attention to the variables to which consideration must be given, and these should always be borne in mind in determining chimney sizes. The various allowances which experience suggested were easily taken care of in using the proposed method.

Mr. Hopping had well empbasized the chaotic state of the art. If reliable results were desired, it was imperative that gas weights be used rather than boiler horsepower. When this was done, no trouble was experienced such as that caused by the different proportions of excess air in hand firing and modern machine firing.

In reply to Mr. Funk, the lack of experimental data affected the accuracy obtained by the use of any method of chimney computation, but in no way detracted from the value of the method itself. So far, friction had been based on volume passing and consequently on average velocity, and that really seemed to be the most convenient way, as it included both surface and fluid friction.

Replying to Professor Christie, the author said that further chimney experiments should include gas analyses at different heights, so that the draft loss and temperature drop within the chimney could be more definitely related to gas weight than can be done at present.

The author agreed with Mr. Uehling as to CO_2 readings and excess air, and could confirm his experience as to serious air leakage losses in very many plants. The use of CO_2 recorders should be increasingly encouraged; and in many cases, a CO_2 recorder connected to the chimney would be very valuable.

It was very interesting that Mr. Toltz had used the method in comparison with others. The advisability of having a simple method could not be gainsaid, and simplicity was an outstanding feature of the system.

Replying to Mr. Frost, the author said that he had found many overloaded chimneys that were not overloaded with useful work but with unnecessary air. Unless flues were airtight, the chimney would be unnecessarily overloaded.

Chimneys should in general be designed on a basis of gas weight. The curves based on boiler horsepower were only intended for approximate or preliminary work.

THE ENGINEERING INDEX

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Exigencies of publication make it necessary to put the main body of The Engineering Index (p. 115-EI of the advertising section) into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.

AERONAUTICS

International Air Congress. The International Air Congress. Engineering, vols. 115 and 116, nos. 3000, 3001 and 3002, June 29, July 6 and 13, 1923, pp. 795–798, 5 11 and 35–39. Abstracts of papers and discussions: June 29: standardization in research; extra-light alloys; airscrew research; slotted wing; aero-dynamic apparatus; unification of standards. July 6: Lanchester-Prandtl theory of airplane lift and drag; airplane engines; air mails; commercial aviation; aircraft testing; airplane control, etc. July 13: Model experiments in aeronautics; lubrication; aerial surveying; aerial navigation and Japan; airships.

AUTOMOBILE ENGINES

Air-Cooled. Air-Cooled Automotive Engines, C. P. Grimes. Soc. Automotive Engrs.—Jl., vol. 13, no. 2, Aug. 1923, pp. 125–133 and (discussion) 133–138, 13 figs. Author believes that universal power unit will be direct air-cooled engine; review of development and description of engineering features of Franklin car.

AUTOMOBILE FUELS

Detonation. Effect of Compression on Detonation and Detonation Control, H. L. Horning. Soc. Automotive Engrs.—Jl., vol. 13, no. 2, Aug. 1923, pp. 144–148 and (discussion) 148–150, 6 figs. Discusses causes of detonation and methods of controlling them; analysis of phenomenon of detonation; statement of actual compression pressures attained without detonation in road tests, and charts showing horsepower developed, etc.

AUTOMOBILES

Buick. New Buick Fours and Sixes Equipped with Front Wheel Band Brakes, J. Edward Schipper. Automotive Industries, vol. 49, no. 5, Aug. 2, 1923, pp. 211–217, 11 figs. Longer wheelbase and radical changes in lines of radiator, hood, fenders and bodies; six-cylinder has detachable head, 1/4-in. longer stroke, larger valves, high-pressure lubrication and stiffer crankshaft.

Hubmobile. Mechanical Refinements and Improved Bodies Feature New Hubmobile. Automotive Industries, vol. 49, no. 5, Aug. 2, 1923, pp. 220–221, 5 figs. Higher power output obtained by use of forged duralumin connecting rods and aluminum-alloy pistons; clutch and gear-set assembly changed, wheelsbase lengthened 3 in.; length of front and rear springs increased.

BOILER FURNACES

Air Preheaters for. The Ljungstrom Air Preheater. Blast Furnace & Steel Plant, vol. 11, no. 8, Aug. 1923, pp. 452–454, 4 figs. Summary of test figures obtained from cylindrical-type marine boiler, fitted with Howden-Ljungstrom air preheater, at works of James Howden & Co., Glasgow.

Oil-Burning. The Franklin-Stephenson Oil-Burning Furnace. Engineering, vol. 115, no. 3000, June 29, 1923, pp. 800–801, 9 figs. Details of furnace and results of tests.

BOILERS

High-Pressure. German Steam Boiler Designed for 850 Pounds Pressure, Bruno Schapira. Power, vol. 58, no. 5, July 31, 1923, pp. 164–166, 4 figs. Steam-power station constructed for its own use by firm of A. Borsig, in Berlin, is designed to carry gage pressure of about 850 lb. per sq. in. at engine throttle; engine will operate with back pressure of 140 lb. and drive air compressor; boiler is designed to generate 15,500 lb. of steam per hr.

CARBURETORS

German Designs. Recent German Carburetor Designs Stress Use of Cheaper Fuels, Benno R. Dierfeld. Automotive Industries, vol. 49, no. 4, July 26, 1923, pp. 177–180, 7 figs. Progress in engine development and demand for special equipment for motorcylces largely responsible for new products; heavy oils handled by double instrument with two float chambers; tests successful.

CHAINS

Weldless. The Manufacture and Properties of Weldless Chains. Engineering, vol. 115, no. 3000, June 29, 1923, pp. 802–803, 15 figs. partly on p. 806. Describes weldless process of chain making and design of rolling mill used for production of chains.

CONDENSERS, STEAM

Air-Leakage Measurement. Condenser Air Leakage Measured at Vacuum Pump Discharge, B. C. Sprague. Power, vol. 58, no. 5, July 31, 1923, pp. 166–167, 3 figs. Practical and simple device which may be of great assistance in maintaining condenser efficiency when circulating water is at summer temperature.

Tubes. The Rapid Corrosion of Condenser Tubes, Guy D. Bengough and R. May. Engineer, vol. 136, no. 3523, July 6, 1923, pp. 7–10, 15 figs. Account of authors' conclusions as to cause of rapid corrosion of condenser tubes which has sometimes occurred during last few years; deals only with corrosion caused by presence of entangled air in circulating water, in estaurine and marine conditions.

COST ACCOUNTING

Small Shops. Cost Keeping for the Small Shop, E. M. Pierce. Am. Mach., vol. 59, no. 6, Aug. 9, 1923, pp. 199–201, 3 figs. Overcoming problems of small jobbing shop by simple chart system; available uses of chart; rejection tags and special-order forms.

CRANES

Wharf, Revolving. 20-Ton Revolving Wharf Crane at Vernon-on-Shore. Engineering, vol. 116, no. 3003, July 20, 1923, pp. 79–80, 8 figs. partly on p. 84. Fixed wharf crane installed by British Admiralty at their naval establishment is of the three-motor type, and will lift 20 tons at 30-ft. radius and 10 tons at 50 ft. radius.

CYLINDERS

Airplane-Engine, Machining. Machining Steel Cylinder Sleeves of the Wright Aviation Engine, Fred H. Colvin. Am. Mach., vol. 59, nos. 5 and 6, Aug. 2 and 9, 1923, pp. 171 173 and 205–207, 22 figs. Aug. 2: Turning, boring, and threading long, thin sleeves with interlocking flanges; special tools, fixtures and gages for securing heat-radiating contacts. Aug. 9. Cutting flanges which make cylinders interlocking; fixtures and tools for boring valve openings and seats.

FORGING

Flow of Metal. The Flow of Metal During Forging, L. A. Danse. Forging & Heat Treating, vol. 9, no. 7, July 1923, pp. 304–307, 5 figs. Discussion of Massey's investigation on action of metal under hammer and press; actual forgings deeply etched plainly reveal flow of metal.

FOUNDRIES

Cost Accounting. Accounting for Foundry Overhead Expense, F. C. Everitt and Johnson Heywood. Iron Age, vol. 112, nos. 2, 3 and 6, July 12, 19 and Aug. 9, 1923, pp. 67–71, 147–150 and 340–342, 12 figs. Attempt to give simplest possible method of distributing general expenses equitably; steam and power considered; allocation of general expenses. How expenses of core making, molding, cleaning and annealing may be classified.

Foundry Costs Simplified, Alfred Baruch. Foundry, vol. 51, no. 15, Aug. 1, 1923, pp. 616–618, 3 figs. Methods of establishing wages and their advantages and disadvantages; standard time and budget system form basis of accounting; time studies.

Steel. Alabama Foundry Saves Labor, E. C. Krentzberg. Iron Trade Rev., vol. 73, no. 3, July 19, 1923, pp. 171–175, 9 figs. New steel foundry of Tennessee Coal, Iron & Railroad Co. and its equipment; materials handled automatically as far as possible; monthly capacity, 1400 tons.

GEARS

Measuring Machines. Gear-Measuring Machine. Engineering, vol. 116, no. 3004, July 27, 1923, pp. 104–109, 28 figs. Gear-measuring machine designed and constructed at Nat. Physical Laboratory, for measuring individual specimens, such as spur and helical, plain and spiral bevel and worm wheels, and for recording errors in running of combined gears.

HYDRAULIC MACHINERY

Pressure Intensifier. Hydraulic Pressure Intensifier, John N. Sioussa. Machy. (N. Y.), vol. 29, no. 12, Aug. 1923, pp. 948–949, 4 figs. Describes intensifier designed for plant requiring equipment capable of producing pressure of 125,000 lb. per sq. in.

INTERNAL-COMBUSTION ENGINES

Spark Advance. Spark-Advance in Internal-Combustion Engines, G. B. Upton. Soc. Automotive Engrs.—Jl., vol. 13, no. 2, Aug. 1923, pp. 111–121 and 172–174, 21 figs. Review of existing data, relating to explosion time as affected by mixture ratio, size of combustion chamber, turbulence, dilution with dead or exhaust gases and temperatures preceding explosion; factors that affect explosion time of engine; mathematical expressions for their laws of action, and numerical values of constants for turbulence and dilution.

LOCOMOTIVES

4-8-2. 4-8-2 Type Locomotive for the Denver and Rio Grande Western Railroad. Engineering, vol. 116, no. 3001, July 6, 1923, pp. 26–27, 21 figs. partly on supp. plate. Locomotives of this type are believed to be the heaviest passenger engines extant.

Mountain Type. Canadian National Mountain Type Locomotive, C. E. Brooks. Ry. Age, vol. 75, no. 5, Aug. 4, 1923, pp. 203–205, 1 fig. Known as U-1-a class; have total weight (without tender) of 339,000 lb.; tractive power is 49,600 lb. See also Ry. Mech. Engr., vol. 97, no. 8, Aug. 1923, pp. 554–557, 4 figs.

MILLING MACHINES

High Speeds, Adjusting for. Adjusting Milling Machines for High Speeds, C. W. Metzger. Machy. (N. Y.), vol. 29, no. 12, Aug. 1923, pp. 972–973, 2 figs. Methods of overcoming difficulties sometimes met with when milling machines are speeded up for stellite cutters.

MOLDS

Steel, Hobbing of. Making Steel Molds by Hobbing. Machy. (N. Y.), vol. 29, no. 12, Aug. 1923, pp. 936–938, 2 figs. Process of sinking duplicate impressions in mold dies by use of hobs in conjunction with enormous hydraulic pressure.

MONEL METAL

Fatigue Limit. The Fatigue Limit and Proportionality of Monel Metal. Engineering, vol. 116, no. 3003, July 20, 1923, p. 88, 3 figs. Account of experiments made with Haigh alternating-stress machine to investigate endurance of monel-metal specimens prepared in different ways.

MOTOR BUSES

Fuel-Economy Tests. One Hundred Ton-Miles Per Gallon, J. B. Fisher. Soc. Automotive Engrs.—Jl., vol. 13, no. 2, Aug. 1923, pp. 139–143, 4 figs. Account of series of tests on motor buses carried out in 1922 at Waukesha, Wis., with purpose of acquiring data on requirements of buses from standpoint of power requirements and fuel economy, and of analyzing discrepancy so often found between performance of engine on test block and fuel economy obtained from same engine under actual service conditions.

PIPE, CAST-IRON

De Lavaud Process. The Stanton Spun Iron Pipe. Engineer, vol. 136, no. 3526, July 27, 1923, pp. 104–106, 11 figs. Describes centrifugal pipe-casting machine devised by De Lavaud, and plant in Stanton, England, where De Lavaud system is employed; characteristics of pipe.

PISTON PINS

Quantity Production. Produces Piston Pins in Quantity. Iron Trade Rev., vol. 73, no. 3, July 19, 1923, pp. 182–183, 4 figs. Piston pins are finished accurately and rapidly on centerless-type grinding machine; each finished pin is inspected closely for size and parallelism under dial gages.

PYROMETERS

Ardometer. A New Form of Radiation Pyrometer, Huber Hermanns. Forging & Heat Treating, vol. 9, no. 7, July 1923, pp. 319–320, 4 figs. Ardometer, manufactured by Siemens & Halske, is particularly suited for shop use and can be subjected to rough handling; permanent installation and quick reading are important features.

RAILWAY SIGNALING

Train-Order Signals. Use of Train-Order Signals at Interlockings. Ry. Age, vol. 75, no. 5, Aug. 4, 1923, pp. 193–195, 4 figs. Tendency is to use interlocking signal as train-order signal in order to eliminate confusion.

ROLLING MILLS

Weldless Rings, Rolling. Rolling Steel and Nonferrous Rings. Iron Age, vol. 112, no. 4, July 26, 1923, pp. 204–206, 7 figs. How weldless product, such as ring-gear blanks, is made on commercial scale at Cleveland, O.

SAND, MOLDING

Testing. Test Sand with Doty Machine, R. F. Harrington, M. L. MacComb and M. A. Hosmer. Foundry, vol. 51, no. 15, Aug. 1, 1923, pp. 606–610, 3 figs. Determine effect of moisture on bond of new sand, results from hand mulling and machine mulling, and effect of grain size on bond of sand Paper presented before Am. Foundrymen's Assn.

SCREW THREADS

Measurement. Modern Methods of Thread Measurement, Charles L. Burns. Am. Mach., vol. 59, no. 6, Aug. 9, 1923, pp. 217–219, 6 figs. Comparison of ring gages; three-wire and projection methods; defects of former and economy of latter.

STANDARDIZATION

Preferred-Number Series. A New Tool For Standardizers, F. J. Schlink. Am. Mach., vol. 59, no. 2, July 12, 1923, pp. 45–48, 3 figs. Preferred-number series and their place in standardization; systems adopted by German and French standards bodies; inception of idea in America and progress made.

STEAM-ELECTRIC PLANTS

Chocolate Factory. Industrial Power Plant of H. O. Wilbur & Sons, Inc., Philadelphia, Pa., J. Hanley Wilkers. Power, vol. 58, no. 6, Aug. 7, 1923, pp. 204–208, 6 figs. Modern plant replaces small engine-driven plant; total generating capacity is 2260 kw.; process steam is extracted from main units; atmospheric cooling tower is mounted on roof.

STEAM POWER PLANTS

Present Tendencies. The Power Plant of Today, C. F. Hirshfeld. Power, vol. 58, no. 5, July 31, 1923, pp. 168–170. Author reviews present tendencies in large-plant design, employing higher pressures together with regenerative and reheating cycles, and questions whether there is sound reason behind these innovations; discusses powdered coal versus stokers.

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Mechanical Engineering

The Monthly Journal Published by

The American Society of Mechanical Engineers

Publication Office, 207 Church Street, Easton, Pa. Editorial and Advertising Departments at the Headquarters of the Society, 29 West Thirty-ninth Street, New York

Volume 45 October, 1923 Number 10

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ADVERTISING

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Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879.
Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921.

H. Sjövall

G. M. Deming

J. C. Smallwood

J. A. Wilson

C. F. Roby

K. Heindlhofer

Contributors to This Issue

J. A. Wilson, secretary and assistant director of the Royal Canadian Air Force, writes on The Control of Civil Aviation. Mr. Wilson was born in 1879 in Broughty Ferry, Scotland, and is a graduate of St. Andrews University. After training as a mechanical engineer with various engineering firms in Scotland, he went to India in 1901. The climate there did not agree with him and he left India for Canada where he was engaged in construction and railroad work until 1910, when he entered the service of the Dominion Government as assistant director of stores in the Naval Service. In 1912 he was appointed Director of Stores and Contracts, and in 1918 became Assistant Deputy Minister of the Naval Service with special duties in connection with the organization of the Royal Canadian Naval Air Service. During the war he had charge not only of all naval stores in the Dominion but also of the work of establishing the Overseas Transport Service.

After the armistice the Canadian Air Board was created and Mr. Wilson took a large part in the preliminary organization work. In 1920 he became permanent secretary of this Board and three years later, he was appointed secretary and assistant director of the Royal Canadian Air Force.

Mr. Wilson is keenly interested in flying himself and has flown in all parts of the Dominion where operations have been undertaken with a view to gaining first-hand knowledge and experience of the work. He is an associate-member of the Engineering Institute of Canada, and belongs to a number of clubs organized for outdoor sports.

* * * * *

Julian C. Smallwood, author of Blended Fuels for Automotive Engines, is associate-professor of mechanical engineering at Johns Hopkins University. He was born in New York City in 1881. He received his M.E. from Columbia University in 1903 and his M.A. from Johns Hopkins in 1917. After a few years of factory and construction work Professor Smallwood became interested in experimental engineering and was engaged as assistant in the materials-testing laboratory of Columbia University. There he developed an inclination toward university work which led to his becoming successively an instructor in the University of Pennsylvania, an associate-professor of experimental engineering in Syracuse University, and, in 1916, teaching fellow at Johns Hopkins University.

During these years Professor Smallwood has conducted much research and engaged in various classes of consulting engineering.

He is an active member of the A.S.M.E. and is secretary-treasurer of the Baltimore Section.

* * * * *

K. Heindlhofer and Harold Sjövall, co-authors of the paper in this issue on Endurance-Test Data and Their Interpretation, are both research engineers with the S K F Industries, Philadelphia, Pa. Mr. Heindlhofer was born in March, 1883, in Pécs, Hungary. He is a graduate of the Federal Polytechnicum of Zurich. In 1909 he came to the United States, where his first position was as designer with the Edison Phonograph Works in Orange, N. J. He held a similar position with the Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa., and later was connected with the Union Switch & Signal Co., Swissdale, Pa., as research engineer. Before becoming associated with the S K F Industries he was in charge of the laboratories of the Bosch Magneto Co., Springfield, Mass.

Mr. Sjövall was born in September, 1893, in Bångbor, Sweden. He was graduated from the Royal Institute of Technology at Stockholm in 1918 with the degree of E.E. For two years he was at the laboratories of the S K F Ball Bearing Co. at Gothenburg, Sweden, engaged in mathematical and mechanical research and magnetic analysis of hard steel. He came to this country in 1920 and since that time has been connected with the S K F research laboratory.

* * * * *

S. Timoshenko, whose paper on Bending Stresses in Curved Tubes of Rectangular Cross-Section is included in this issue, received his degree in civil engineering in 1901 from the École des Ponts et Chaussées of St. Petersburg, Russia. Soon after this, he accepted an appointment as instructor at the Polytechnic Institute of St. Petersburg, where one year later he became assistant professor of applied mathematics. In 1906 he was called to the Polytechnic Institute of Kieff, to occupy the chair of applied mathematics. He received his doctor's degree the following year. From 1914 to 1918 he occupied the newly created chair in the theory of elasticity as applied to ships at the Polytechnic Institute in St. Petersburg. Upon coming to this country Dr. Timoshenko became connected with the Vibration Specialty Co. of Philadelphia, as consulting engineer. He is at present in the research department of the Westinghouse Electric & Manufacturing Co., East Pittsburgh, Pa.

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George M. Deming who contributes a paper on The Strength of Bolt Threads as Affected by Inaccurate Machining, is at present an instructor in the plant of the Pacific Telephone and Telegraph Co., Seattle, Wash. He was born in 1893 in San Bernardino, Cal. He is a graduate of the University of Washington. During the war Mr. Deming served in the chemical warfare branch of the Army. Early in 1919 he became a laboratory assistant and later assistant engineer physicist in the Bureau of Standards, Washington, D. C., where he was located until he became connected with his present firm.

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C. F. Roby, who is a graduate of the University of Cincinnati, class of 1922, presented in part fulfillment of the requirements for the degree of mechanical engineer, a thesis on Chip Formation by Milling Cutters, an abstract of which appears in this issue. His coöperative work in connection with his university course was with the Cincinnati Milling Machine Co., by which concern he is now employed as plant engineer.

Management Week, October 22-27

The National Committee on Management Week is rapidly building up its organization for the direction of programs throughout the country during the week of October 22-27. Some fifty-odd A.S.M.E. Local Sections and twenty-five sections of other societies are expected to participate. For details of the plans see current issues of the A.S.M.E. News.

MECHANICAL ENGINEERING

Volume 45 October, 1923 No. 10

The Control of Civil Aviation

The Necessity of a Recognized System for the Regulation of Air Traffic—International Control Through the International Convention for Air Navigation—Domestic Control as Illustrated by the Operation of the Canadian Air Board Act

By J. A. WILSON,[1] OTTAWA, CANADA

A CENTURY AGO man traveled on foot or on horseback, by mail coach or by ship, and the state took little interest in his health or safety. Today our ships are built, equipped, and navigated to government standards; the operation of our railroads is controlled in the interest of our safety; and our motor cars are licensed and restricted by speed laws and regulations on every side. The growth of this control of transportation by the state provides a fascinating field for study. Shipping and steamboat-inspection acts and the regulation of railway and highway traffic have been forced by the pressure of public opinion and circumstances on unwilling governments. Their action has usually lagged behind what is actually necessary and only the minimum of interference to insure the public safety has been enforced. Such regulations as have been enacted in different parts of the world have been the fruit of experience, and in most cases have been proved necessary under actual working conditions.

The control of aviation has had quite a different history. There has been no such gradual development. The flying machine awaited for many years the invention of an engine light enough to make flight possible. Once this engine was successfully built, flight was accomplished and progress along natural lines proceeded. In the ten years preceding the war there was quiet but steady development of aircraft by firms, individuals, and governments. Each machine built was an improvement on the previous one and it is probable that, had there been no war, the design of aircraft for civil purposes would have been further advanced today. As flying developed there would have been a corresponding growth in air traffic, and necessity would have enforced some measure of state control.

The war of 1914–1919 intervened, and the normal development of aviation ceased. For four years aircraft were considered as weapons of offense and defense only. Billions of dollars were thrown into their manufacture. New engines of greater and still greater power were built. Aircraft design was given a false direction and, though assisted lavishly, was hampered and impeded by the necessity for mass production. Economy of operation, an essential for commercial work, was not considered. When peace came a great development in the aircraft industry had taken place throughout the world. This was not on sound lines from a civil-aviation viewpoint, as there had been no corresponding development of the peacetime use of aircraft. The armistice brought aircraft production to a sudden standstill. No effort had been made to accustom the public to the new form of transportation; no machines intended for the carriage of goods, mails and passengers, nor air traffic systems, had been developed; and no regulations had been framed for the control of the new form of transportation. Aircraft of immense possibilities had been produced, however, and the eyes of the world had been opened to the future of aerial transportation.

The pause which has ensued in the progress of civil aviation has been caused by the lack of two factors essential to the success of commercial aviation. These are the confidence in, and familiarity with, aerial transportation on the part of the public and the creation of aerial transportation systems. Before flying can succeed as a commercial form of transportation these must be created, and some time must yet elapse before their growth overtakes the development of aircraft, hastened unnaturally during the war. To assist this growth the first necessity was the institution of a recognized system for the regulation of air traffic.

International Control

Previous to the war the only step in this direction was the institution, by the International Aeronautical Federation, formed in 1910 with headquarters in France, of a standard for pilots' certificates. These certificates were recognized everywhere and still form the basis of the present-day pilots' qualifications.

Flight is untrammeled by artificial or natural boundaries. The air provides a free and uniform passage everywhere. Aircraft travel with equal ease over land or sea, rivers, plains or mountains. Frontiers or customs barriers mean nothing in the air. Because of this, some form of international control is essential and uniformity in standardization and regulation most desirable. Steps were therefore taken at the Peace Conference, where were gathered together the principal nations of the world, to form a code for the control of civil aviation. A sub-commission of the Peace Conference at Versailles sat during the spring of 1919 and considered the matter in detail. The result was the International Convention for Air Navigation.

The sub-commission which drew up the International Convention was composed of representatives of the allied and associated powers, including the British Empire, the United States, France, Belgium, Italy, and Japan. It was signed by the following powers: Belgium, Bolivia, the British Empire, France, Greece, the United States of America, Brazil, China, Cuba, Ecuador, Guatemala, Italy, Japan, Panama, Poland, Portugal, Roumania, the Kingdom of the Serbs, Croats, and Slovenes, Siam, Czechoslovakia, and Uruguay; and was subsequently ratified by Belgium, Bolivia, Brazil, the British Empire, France, Greece, Japan, Portugal, the Kingdom of the Serbs, Croats, and Slovenes, and Siam.

It should be noted that, though the United States Government was a signatory to the Convention, it has not yet ratified it and that, therefore, the question of its adherence to the terms of the Convention is still in abeyance.

The following brief synopsis of the Convention will be of interest as it forms the groundwork for the regulation of air traffic and covers the subject fully.

SYNOPSIS OF THE INTERNATIONAL CONVENTION FOR AIR NAVIGATION

Chapter I—General Principles

The complete and exclusive sovereignty of each state over the air space above its territory is recognized (Art. 1).

Each state shall accord freedom of innocent passage above its territory to aircraft of other states, provided that the terms of the Convention are observed, and further, that any regulations made by a state as to the admission over its territory of the aircraft of another state, shall be applied without distinction (Art. 2).

Prohibited areas over which aircraft may not fly may be established (Art. 3).

Chapter II—Nationality of Aircraft

Each state shall register and mark its aircraft in accordance with the provision of Annex A to the Convention.

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Presented at the Spring meeting, Montreal, Canada, May 28 to 31, 1923, of The American Society of Mechanical Engineers. Slightly abridged. All papers are subject to revision.

No aircraft shall be entered on the register of a state unless it belongs wholly to nationals of that state, and further, no incorporated company can be registered as the owner of an aircraft unless it possesses the nationality of the state in which the aircraft is registered; unless the president or chairman of the company and at least two-thirds of the directors possess that nationality; and the company fulfills all other conditions which may be prescribed by the law of the state (Art. 7).

No aircraft may be validly registered in more than one state (Art. 8). States shall exchange information as to the aircraft shown on their official registers (Art. 9).

Chapter III—Certificates of Airworthiness and Competency

Every aircraft engaged in international air navigation shall be provided with a certificate of airworthiness by the state whose nationality it possesses (Art. 11). The qualifications for this certificate are given in Annex B to the Convention.

Personnel operating aircraft shall be properly licensed (Art. 12). The standards of competency required from pilots, navigators, and engineers are laid down in Annex E.

Certificates of airworthiness and competency issued by one state shall be recognized as valid by the other states, but each state has a right to refuse to recognize, for the purpose of flights over its own territory, certificates of competency or licenses granted to one of its own nationals by another contracting state (Art. 13).

No wireless apparatus shall be carried without a special license issued by the state, and further, any aircraft used in public transport and capable of carrying ten or more persons must be equipped with sending and receiving apparatus (Art. 14).

Chapter IV—Admission to Air Navigation above Foreign Territory

Aircraft of a contracting state have the right to cross over the space of another state without landing, but shall follow the route fixed by that state and must land if required to do so at an aerodrome fixed by the latter (Art. 15).

Each state is permitted to establish reservations and restrictions in favor of its national aircraft in connection with the carriage of goods and persons between points in its own territory (Art. 16).

If a state establishes such reservations, other states may retaliate by enforcing similar restrictions against its aircraft, even though the latter do not restrict aircraft of other foreign states which have not enacted such restrictions in favor of their own national aircraft (Art. 17).

Chapter V—Rules to be Observed on Departure, When Under Way, and on Landing

Every aircraft engaged in international navigation shall be provided with certificates of airworthiness and registration. Its crew shall be properly licensed. It shall carry a list of its passengers, bills of lading, and manifest covering its freight, aircraft log books and wireless licenses, if so equipped (Art. 19).

Aircraft in distress shall be entitled to assistance in landing (Art. 22).

The salvage of aircraft wrecked at sea shall be dealt with according to the principles of maritime law in the absence of any other agreement (Art. 23).

Any aerodrome which is open to public use for payment of charges shall be open on the same terms to the use of aircraft of other contracting states (Art. 24).

The observance of the rules of the air and the carrying of lights and signals for night flying are made obligatory (Art. 25).

Chapter VI—Prohibited Transport

The carriage by aircraft of explosives, arms, and munitions of war is forbidden in aircraft engaged in interstate flying (Art. 26). The prohibition and regulation of the use of photographic apparatus in aircraft is permitted to each state (Art. 27). As a measure of public safety the carriage of objects other than those mentioned above may be subject to restriction (Art. 28), and such restrictions shall be applied equally to national and foreign aircraft (Art. 29).

Chapter VII—State Aircraft

State aircraft are divided into two classes, military aircraft (i.e., those commanded by a person in military service—Art. 31), and aircraft exclusively employed in state service, such as posts, customs, police. State aircraft not coming within these two categories shall be treated as private (or commercial) aircraft and shall be subject to the provisions of the Convention (Art. 30).

No military aircraft shall fly over the territory of another state or land thereon without special authorization. If such authorization is enjoyed it shall be entitled to similar privileges as a foreign ship of war (Art. 32).

Chapter VIII—International Commission for Air Navigation

This chapter provides for the creation of a permanent commission for air navigation consisting of two representatives each of the United States of America, France, Italy, and Japan; one representative of Great Britain and one of each of the British Dominions and India; and one representative of each of the other contracting states. Its duties are:

- *a* To receive or make proposals for the amendment of the Convention
- *b* To carry out the duties imposed on it by the Convention
- *c* To amend the provisions of the first seven Annexes to the Convention (particulars given below)
- *d* To collect and communicate to contracting states information of every kind relating to air navigation
- *e* To collect and communicate to all contracting states all information relating to wireless telegraphy, meteorology, and medical science which may be of interest to air navigation
- *f* To insure the publication of maps for air navigation
- *g* To give its opinion on questions which may be submitted to it by contracting states.

The expenses of this Commission shall be borne by the contracting states in proportion to the number of votes at their disposal.

Chapter IX—Final Provisions

The contracting states undertake to coöperate in the collection and dissemination of meteorological information; the publication of standard aeronautical maps; the establishment of a uniform system of ground marks for air stations; and the establishment of facilities for the use of wireless (Art. 35).

The present Convention shall not be construed as preventing the contracting states from concluding special agreements in regard to air navigation provided that notification of these is given to the International Commission (Art. 36).

Provision is made for the arbitration of disputes arising out of the interpretation of the Convention (Art. 37).

In the case of war the provisions of the Convention shall not affect the freedom of action of the contracting states either as belligerents or as neutrals (Art. 38).

States which have not taken part in the war of 1914–1919 shall be permitted to adhere to the present Convention (Art. 41).

The annexes to the Convention are of great importance and lay down in considerable detail the action necessary on the part of the contracting states for the adequate control of civil aviation. They are briefly as follows:

Annex A—The Marking of Aircraft

A system is instituted by which all civil aircraft are marked by groups of five letters. The first letter is known as the nationality mark. These have been allotted as follows:

TABLE OF MARKS TO BE BORNE BY AIRCRAFT

(Annex A of the Convention relating to the regulation of aerial navigation, signed in Paris October 13, 1919, completed by the decisions of the I.C.A.N. dated July 13 and October 25, 1922)

Country	Nationality Mark	Registration Marks
United States of America	N	All combinations made in accordance with the provisions of Section 1(a) of Annex A of the Convention, using a group of 4 letters out of the 26 of the alphabet, each group containing at least one vowel, e.g., ACDJ, PURN.
British Empire	G	
France	F	
Italy	I	
Japan	J	
Hedjaz	A	All combinations made with H as first letter
Nicaragua	A	All combinations made with N as first letter
Lettonia	B	All combinations made with L as first letter
Bolivia	C	All combinations made with B as first letter
Cuba	C	All combinations made with C as first letter
Switzerland	C	All combinations made with H as first letter
Portugal	C	All combinations made with P as first letter
Roumania	C	All combinations made with R as first letter
Uruquay	C	All combinations made with U as first letter
Ecuador	E	All combinations made with E as first letter
Haiti	H	All combinations made with H as first letter
Netherlands	H	All combinations made with N as first letter
Siam	H	All combinations made with S as first letter
Czechoslovakia	S	All combinations made with B as first letter
Guatemala	L	All combinations made with G as first letter
Liberia	L	All combinations made with L as first letter
Luxemburg	L	All combinations made with U as first letter
Spain	M	All combinations made with A, B, C, D, E, F, G, H, I, J, K, L, M, or N as first letter
Brazil	P	All combinations made with B as first letter
Poland	P	All combinations made with P as first letter
Belgium	O	All combinations made with B as first letter
Peru	O	All combinations made with P as first letter
Greece	S	All combinations made with G as first letter
Panama	S	All combinations made with P as first letter
China	X	All combinations made with C as first letter
Honduras	X	All combinations made with H as first letter
Kingdom of the Serbs, Croats, and Slovenes	X	All combinations made with S as first letter

Annex B—Certificates of Airworthiness

Provides for the institution of standards of workmanship material and construction by the Commission. Until these are agreed on each state may set its own standards.

Annex C—Log Books

Provides for the keeping by aircraft of the following books: Journey log, aircraft log, engine log, and a signal log.

Annex D—Rules as to Lights and Signals Rules of the Air

Systems are adapted, generally speaking, from rules for marine navigation, with such alterations as the conditions require.

Annex E—Minimum Qualifications Necessary for Obtaining Certificates as Pilots and Navigators

Lays down in detail the minimum qualifications required by the different classes of personnel engaged in aviation, pilot navigators, and air engineers.

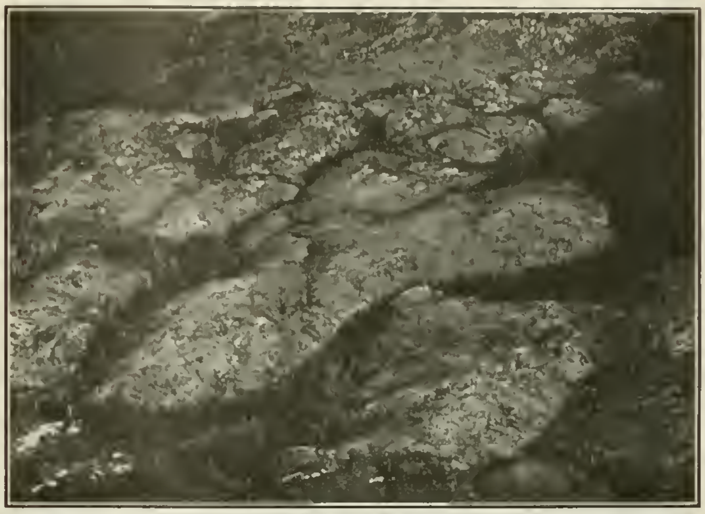
Annex F—International Aeronautical Maps and Ground Markings

Provides for the preparation of a universal system of maps on the International 1 : 1,000,000 scale, and also for a universal system of ground markings for aerodromes.

Annex G—Collection and Dissemination of Meteorological Information

Provides for the collection and dissemination of weather forecasts and the preparation of special reports on meteorology.

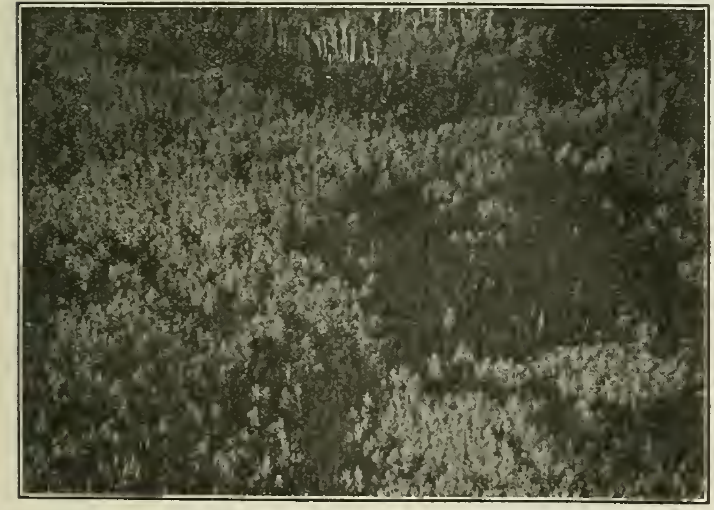
Forest Fire in Northern Ontario



Devastation from Fire

Typical Lake and Forest Country in Northern Ontario, Showing Burnt and Timbered Area

Closeup of Portion of Island in Picture to Left, Showing How Timber Types Can Be Distinguished by Airmen



Typical Mixed Forest Country With Coniferous and Deciduous Trees. Note How Easily Each Species Can Be Distinguished While Flying

Hudson Bay Fort, Norway House, in Northern Manitoba, a Remote Outpost Formerly the Center of the Hudson Bay Activities Throughout the North-American Continent

Peace-Time Uses of Aircraft in Canada

As the author points out later in the article, the development of commercial aviation in Canada at the present time is purely as an auxiliary to existing services for forest-fire protection and survey and for work in the more remote parts. There the methods of travel are slow, laborious, and uncertain, and the only competitors are the canoe, pony, and dog train. The photographs on this and the following pages, taken from an airplane, illustrate these peace-time uses of aircraft in Canada.

Annex H—Customs

Deals with customs and the institution of customs aerodromes and regulations applicable to the import and export of goods by air.

Did space permit there are many points in the Convention which could be further elaborated to good purpose. This is especially true of the annexes, which are of the greatest value and provide, on the whole, a thoroughly sound basis for the control of civil aviation and for systems to collect and disseminate information not only on aviation but on the subjects of wireless communication and meteorology, without which the conduct of international flying cannot be efficiently conducted. The limits of this paper, however, will not permit of this.

The International Commission formed under Chapter VIII of the Convention is now functioning. It has held three general meetings. Committees have been formed to deal with the duties imposed on it by the Convention in relation to the preparation of aeronautical maps, the operation of wireless in connection with aviation, medical standards for air personnel, standards of airworthiness for machines, and other kindred subjects.

The Commission has already under consideration various modifications and amendments to the Convention which experience has proved necessary. As aviation develops this will continue to be the case. In the Commission the world has now a permanent body for the consideration of such questions. If properly used and directed it will insure the maintenance of universal aviation standards, adequate for their purpose, and in addition a body for their revision as new conditions arise.

Domestic Control

Having considered the question of international control, we pass on to the question of domestic control by each state. Canadian conditions are naturally those most familiar to the author and will therefore be dealt with to illustrate the subject. Similar principles to those proved sound in actual practice in Canada will hold good elsewhere.

The Air Board Act, passed by the Canadian Parliament in June, 1919, instituted an Air Board presided over by a Minister of the Crown having full powers to deal with aeronautics in all its phases. Under legislation passed in 1922 for the creation of a Department of National Defense, the powers of the Air Board are vested in the Minister of Defense. The control of aeronautics, however, remains undivided.

Under Section 3 of the Air Board Act the following duties in regard to the control of civil aviation are laid on the Board:

a To supervise all matters connected with aeronautics

b To study the development of aeronautics in Canada and in other countries, and to undertake such technical research as may be requisite for the development of aeronautics, and to coöperate with other institutions in carrying out such research

f To prescribe aerial routes

h To take such action as may be necessary to secure, by international regulation or otherwise, the rights of His Majesty in respect of His Government of Canada in international air routes

k To investigate, examine, and report on all proposals for the institution of commercial air services within Canada or the limits of the territorial waters of Canada.

Typical Forest and Lake Country in Northern Manitoba and Saskatchewan
(This and similar pictures have been used for mapping these regions by means of the grid method.)

Under Section 4 the Board is given power to "regulate and contro aerial navigation over Canada and the territorial waters of Canada," and in particular, but not to restrict the generality of the foregoing terms, it may, with the approval aforesaid, make regulations with respect to

a Licensing of pilots and other persons engaged in the navigation of aircraft, and the suspension and revocation of such licenses

b The registration, identification, inspection, certification, and licensing of all aircraft

c The licensing, inspection, and regulation of all aerodromes and air stations

d The conditions under which aircraft may be used for carrying goods, mails, and passengers, or for the operation of any commercial service whatsoever, and the licensing of any such services

e The conditions under which goods, mails, and passengers may be imported and exported in aircraft into or from Canada or within the limits of the territorial waters of Canada, or may be transported over any part of such territory

f The prohibition of navigation of aircraft over such areas as may be prescribed, either at all times or at such times or on such occasions only as may be specified in the regulation, and either absolutely or subject to such exceptions or conditions as may be so specified

g The areas within which aircraft coming from any places outside of

Canada are to land, and the conditions to be complied with by any such aircraft

h Aerial routes, their use and control

i The institution and enforcement of such laws, rules, and regulations as may be deemed necessary for the safe and proper navigation of aircraft in Canada or within the limits of the territorial waters of Canada.

Under clause 2 of this section, "any person guilty of violating the provisions of any such regulation shall be liable, on summary conviction, to a fine not exceeding one thousand dollars; or to imprisonment for any term not exceeding six months, or to both fine and imprisonment."

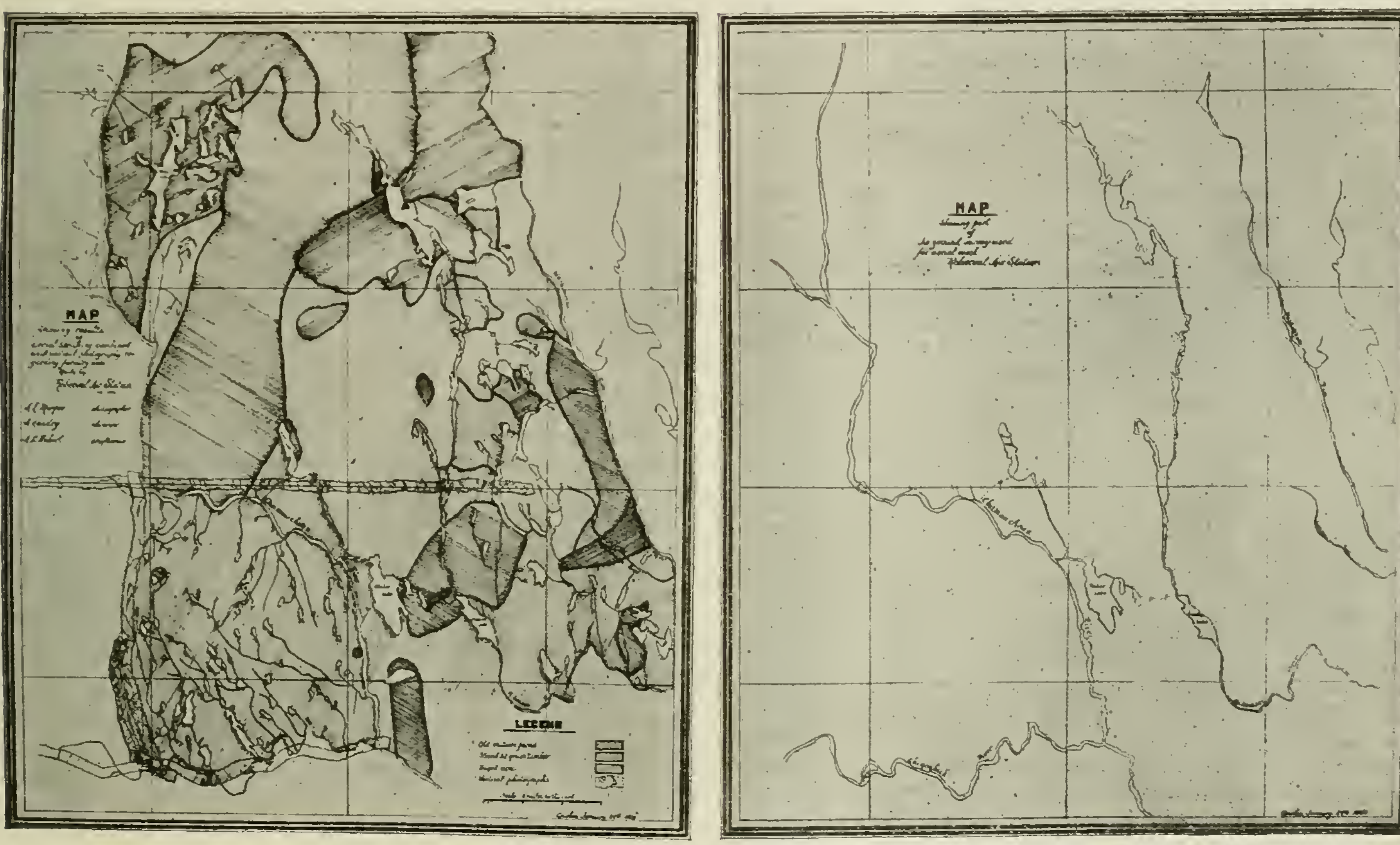
Section 3 provides for the enactment of the necessary regulations as follows:

All regulations enacted under the provisions of this Act shall be published in the *Canada Gazette*, and, upon being so published, shall have the same force in law as if they formed part of this Act. Such regulations shall be laid before both Houses of Parliament if Parliament is then sitting, and if Parliament is not then sitting, then within ten days after the next meeting thereof.

To illustrate the working of the system, let it be supposed that a company is being formed for the conduct of commercial aviation in this country. They apply to the State Department for incorporation. Those terms of their charter which concern the conduct of air services are referred for advice to the Department of National Defense.

Air Harbors

As no aircraft may be operated except from licensed air harbors, the company leases or buys a site for its air harbor, and applies for its license. An inspector visits the site and reports on its suitability. The points given special attention are the wind conditions and, in the case of a seaplane station, its exposure to heavy seas; the area available for taking off and alighting; whether it is surrounded by buildings or natural objects likely to obstruct the taking off or landing of machines; the surface of the ground and the nature of the soil. If the site is found satisfactory a license is issued. Air harbors have been divided into the following classes:



Illustrating the Results of Sketching from the Air in Mapping Forest Types

(The left-hand map shows supplementary topographical details added to original map, which showed only main water courses and, in addition, the nature of the forest in the district. Extensive use of this method is being made for exploratory mapping of timber resources in Canada.)

It will be seen from the above that adequate powers for the control of civil aviation exist in Canada.

Following out the duties imposed on the Board by this legislation, an order-in-council was passed on December 31, 1919, approving and promulgating the Canada Air Regulations 1920, which cover in detail the air law of Canada and provide a complete set of rules which after three years' experience have proved in practice to be fundamentally sound, though in minor details they may require modification and amendment. These regulations conform in essentials to the International Convention, and the ideas and standards laid down in it are their basis. Diversions on minor points were found necessary to meet Canadian conditions. These are now being taken up through the Commission for adjustment and every effort will be made to hold a uniform code with other states. This is considered of vital importance to the future of international flying.

The administration of the Canadian Air Regulations is carried out by the Department of National Defense through the Controller of Civil Aviation.

I Airship harbors (i.e., for lighter-than-air machines)

II Aerodromes and seaplane stations, subdivided as follows:

- *a* Public air harbors open day and night
- *b* Public air harbors open by day only (These are open to all traffic on payment of approved landing and storage charges)
- *c* Public customs air harbors open by day and night
- *d* Public customs air harbors open by day only (Recognized by the customs and immigration authorities as ports of entry from foreign countries)
- *e* Commercial air harbors
- *f* Commercial customs air harbors (Limited for the use of the licensees only).

A distinctive ground marking is allotted, depending on the class within which the air harbor comes. A simple system of markings has been devised which show not only the class of air harbor but its size under five divisions, i.e., under 300 yd., 300 to 400 yd., 400 to 600 yd., 600 to 800 yd., aerodromes over 800 yd. and all seaplane stations.

Airworthiness of Machines

The next step is the licensing for airworthiness of the machines. If these are of a type which has been previously certified as airworthy, under the terms of the International Convention in Canada or in any other country, all that is necessary is an inspection by a competent person to ascertain whether they comply in material, workmanship, and construction with the type, and whether they are properly rigged in all respects and their engines and equipment are in good condition. They must also be provided with the necessary instruments for safe flying and log books for the aircraft and engine which show their history. If the inspector is satisfied that the conditions of the Air Regulations have been complied with, the licenses are issued. If any aircraft is of a type not previously certified as airworthy, detailed drawings of it must be submitted to the Department. These are carefully examined by the technical staff, the factors of safety are calculated, and the design analyzed with reference to its stability, flying qualities, safety from fire, etc. This examination is of the greatest importance and it is essential that it should be thoroughly done by a fully competent and experienced staff. The issue of a type certificate by one state means that all machines of that design, if properly built, are recognized as airworthy by all states adhering to the Convention. Mutual recognition by all countries of the certificates of airworthiness of aircraft engaged in international flying is essential, and common standards are therefore desirable.

The standards of design and factors of safety which have been adopted by Canada, in common with Great Britain and the other self-governing dominions of the British commonwealth, are the result of practical experience and research extending over many years. The exceptional freedom from flying accidents in Canada and Great Britain proves that they are sufficient to insure the safety of the machine and its occupants, in so far as that depends on the strength and design of the machine itself.

As all aircraft are not commercial, a digression must be allowed here from our typical case to deal with the airworthiness of the other classes. These are state aircraft and private aircraft. The former are subdivided into two classes: Military aircraft, i.e., those commanded by a person in the military service; and state aircraft, those belonging to the state and employed for its civil uses (postal, police, forestry, etc.). With the first class we are not here concerned, but it is obviously desirable that the second class should be made to conform in every way to the standard of airworthiness set for commercial aircraft and should, in so far as their duties permit, comply with the Air Regulations in all respects. Private aircraft are those used for the private pleasure or business of any person. They may not carry passengers or freight for hire, nor engage in commercial work for compensation of any kind. Such machines require no certificate of airworthiness. It might be held that this exception is dangerous and that the state neglects its duty in not insisting that all aircraft flown should be certified as airworthy. On the other hand, a too rigorous insistence on set standards and types might cramp and hamper the design of new types and make experimental and research work difficult. This exception is made to encourage such work so that the development of new types may be carried on unhampered by restrictions.

Flying Personnel

The next problem before our company is the licensing of its personnel. These are divided into two main classes, flying and ground. The flying personnel are subdivided into two classes, pilots and navigators, each of which is subdivided in accordance with the type of machine that they are qualified to fly. Lighter-than-aircraft pilots are classed as balloon pilots and airship officer pilots, the latter receiving first-, second-, and third-class certificates in accordance with the size of the airship. As the development of lighter-than-aircraft is still in its infancy it is not necessary to go into further details as to the qualifications required for this class of work.

Heavier-than-air-machine pilots are subdivided into private and commercial pilots. The certificate for the former does not authorize its holder to fly for hire, but the candidate must pass a medical examination once each year and a flying test before it is issued. Commercial pilots' certificates are of two classes, for land machines and for water machines. Each class is subdivided into

- *a* Light machines—maximum safe load, including fuel and oil, 1000 lb. or less
- *b* Medium machines—maximum safe load, including fuel and oil, more than 1000 and less than 3000 lb.
- *c* Heavy machines—maximum safe load, including fuel and oil, 3000 lb. or more.

Certificates are granted subject to the holder's passing a medical examination at least every six months. The flying tests include not only tests of skill as a pilot, but a cross-country flight of not less than 175 miles to insure the pilot's capacity for cross-country work and a night-flight test. All classes of pilots are required to pass an examination on the construction, maintenance, and functions of the aircraft, its engine and accessories. They must also have full knowledge of the rules as to lights and signals, rules of the air, and the conduct of traffic in the vicinity of air harbors. They must have a good knowledge of the Canadian Air Regulations and the International Joint Convention for Air Navigation and, in addition, of map reading, orientation, location of position, and elementary meteorology.

The examinations and tests are all of a practical nature and are set by practical flying men with a view to ascertaining as far as possible the actual suitability of the candidate for his work as a commercial pilot.

Air navigators' certificates are provided for, but in the present state of development of aviation have not been found necessary. They are intended for use in the case of large machines of great range, when the navigation of the aircraft will be undertaken by a different officer from the pilot. They are largely based on the master mariner's certificate, modified to meet the new conditions, and will in time undoubtedly fill an important place in aerial transportation.

Ground Personnel—Air Engineers

On this class is thrown the responsibility of maintaining the aircraft in airworthy condition after a certificate of airworthiness is granted by an inspector. The Government inspects every machine at least once a year, but the day-to-day maintenance rests with the air engineer. No aircraft may be operated in this country unless a licensed air engineer is employed to maintain it. This is a very necessary precaution as many present-day pilots, especially the younger men, are careless in regard to the maintenance of their machines. There is nothing to prevent a pilot from qualifying as an air engineer and maintaining his own machine, and in most cases commercial pilots hold the double qualifications. Every day before a flight is taken the air engineer must certify that the machine is, in his opinion, airworthy. The company can now operate with the knowledge that in so far as the state can provide, its premises are suitable, its machines airworthy, and its personnel properly qualified.

Operations

In Canada there has been practically no development of passenger, mail, or express services. Until these are successful in countries where the population is denser, the need for quick transportation more urgent, and the physical difficulties less, it has been felt that these can wait. Our principal and most promising development has been in connection with work in the remoter parts of the country where the methods of travel are slow, laborious, and uncertain, and the only competitors are the canoe, pony, or dog train. There exists a vast field for this class of work in Canada and already a start is being made to develop commercial aviation as an auxiliary to existing services for forest fire protection and survey, the natural immediate outlets for commercial aviation in Canada. Mail and passenger services will follow in time.

Interstate flying between Canada and the United States is commencing between the large cities on either side of the international boundary. The Canadian regulations allow for the entry of machines of American nationality engaged in this traffic. Such machines may only land at an air harbor approved by the customs and immigration authorities. These authorities have shown themselves most anxious to coöperate in the development of air traffic and impose no unnecessary restrictions.

(*Continued on page 613*)

Blended Fuels for Automotive Engines

A Study of Mixtures of Other Fuels with Gasoline with Respect to the Power They Develop, Cost per Horsepower-Hour, and Overall Economy, and Their Value as a Means of Relieving Gasoline Shortage

By JULIAN C. SMALLWOOD,[1] BALTIMORE, MD.

BLENDED FUELS, as the term is used in this paper, are not substitutes for gasoline but mixtures of other fuels with gasoline, the purpose of which is to make a superior, cheaper, or more salable product. There is one mixed fuel, namely, benzol and alcohol, which does not fall in this classification, although it may in the future have considerable importance. Such a fuel is a substitute for gasoline, but since there is no large organization interested in its manufacture and distribution, the supply of benzol is limited, and the cost of alcohol compared with gasoline at present is high, it seems unlikely that this fuel will have much prominence in the near future.

Gasoline blends, listed in the order of their importance, are benzol, kerosene, alcohol, and ether, these being mixed with the gasoline in various proportions. Since benzol is obtained chiefly as a by-product in coke ovens, distribution centers of benzol-blended gasoline are to be found exclusively in cities which support industries requiring coke ovens on a large scale. Even when the blended fuel requires as little as 10 per cent of benzol, there is not enough yield to support distribution beyond a very limited radius. The whole subject is consequently now of only local importance, but as the sources of benzol increase, more and more use will be made of this very desirable fuel.

Considering the present situation, owners and operators of motor vehicles on a small or large scale, in localities where blended fuels are obtainable, must decide upon the relative merits of such fuels at a somewhat higher price per gallon as compared with those of so-called "straight" gasoline. Putting aside all psychological reactions, which form a large part in "results" obtained by individuals during road tests necessarily of inaccurate character, an impartial study must be made of the following claims:

1 That blended fuels give greater power
2 That they give greater economy in fuel consumption
3 That they give better operation of engine
4 That the total cost of operation with blended fuels is less than with gasoline in spite of the higher price per gallon
5 That blended fuels afford a valuable means of relieving gasoline stringency.

In order to make this study thorough, some of the physical properties of three fuels will first be considered, as follows:

	Gasoline	Commercial Benzol	Ethyl Alcohol
Lower heating value, B.t.u. per lb	18,000	17,300	10,800
Gravity, deg. Baumé	60	30	44
Specific gravity	0.737	0.874	0.806
Weight per gal., lb	6.13	7.28	6.71
Lower heating value, B.t.u. per gal	110,500	126,000	72,400
End point on distillation curve, deg. fahr.	437	250	172
Air required for theoretical combustion per lb. of fuel, lb	15	13.3	8.6
Heating value, B.t.u. per lb. of combustible mixture (air and fuel)	1125	1209	1125

The lower heating value is quoted instead of the higher because under no circumstances can the modern gasoline engine make available the heat content of the water of combustion.

Pure benzol, C_6H_6, being a single chemical compound, has a horizontal distillation curve at 176 deg. fahr. Owing to the impurities in the commercial product (toluol, xylol, etc.) its curve rises at about 90 per cent and 176 deg. to the value tabulated.

It will be observed from the table that, although the heating value of benzol in B.t.u. per lb. is less than that for gasoline, its greater density reverses this relation when based on the gallon. Since these fuels are *sold* by the gallon, this appears as a point in favor of benzol.

The last item in the table is obtained by dividing the first item by the number of pounds of combustible mixture; e.g., for gasoline, $18{,}000 \div (1 + 15) = 1125$. This result is the real criterion of power capacity. In general a rich fuel requires more air for combustion. The more air required, the less fuel can be used per cycle in a cylinder of given dimensions. This offsets the apparent advantage of a high-heating-value fuel in so far as maximum engine capacity is concerned. Although the heating value of benzol is 14 per cent greater if based on the gallon, it is only 7 per cent in excess if based on the charge.

Power

From the above consideration it would appear that an engine using unmixed commercial benzol could not develop more than 7 per cent more power than one using straight gasoline. Certainly it cannot be shown on a basis of heating values that a gasoline blended with 10 or 20 per cent of benzol would give an appreciable increment of power over gasoline.

It has been argued that the blended fuel has a lower end point than gasoline. This is undoubtedly the case. Report No. 47 of the National Advisory Committee on Aeronautics shows distillation curves, obtained by the Bureau of Standards, for export aviation gasoline with an end point of 392 deg. fahr., and for gasoline blended with 20 per cent of benzol with a resulting end point of 290 deg. fahr. From this it might be concluded that the greater volatility obtained with the blended fuel will cause better combustion and increased power. It must be remembered, however, that the present-day automobile engine is very well adapted to take care of low end points by hot spots and similar devices. The report quoted above also states that the benzol mixtures show very little gain in power at ordinary altitudes over export aviation gasoline. The latter, of course, is a much superior fuel to that sold at filling stations, but there is no reason to believe that it will develop more power than ordinary gasoline in a well-designed engine running under a constant load. Therefore some conclusion may be formed of the relative merits, in regard to power, of benzol blends and ordinary gasoline from these tests comparing such blends with aviation gasoline.

The National Advisory Committee in Report No. 89 compares export aviation gasoline with a blended fuel containing 40 per cent ethyl alcohol, 35 per cent gasoline, 17 per cent benzol, and 8 per cent toluol, ether, etc. The first had a higher heating value of 120,000 B.t.u. per gal.; the second, 106,000 B.t.u. The power developed with the latter fuel was 4 per cent greater than with former. This increment is hardly worthy of note.

The author's general conclusion is that the blended fuels thus far concocted do not develop appreciably greater engine power than gasoline when the engine is in good condition and is adapted to the fuel.

Economy in Fuel Consumption

The operator should not be misled by quotations of efficiency or of pounds or gallons per horsepower-hour. What really concerns him is the number of cents he must pay for the fuel per horsepower-hour or per mile. For example, in the October, 1922, issue of the S.A.E. *Journal* some tests are quoted to show the superiority of benzol-blended gasoline, as follows:

	Gasoline	"Motor Benzol"
Gal. per hp-hr.	0.122	0.109
Thermal efficiency, per cent	18.5	16.9
Cost of fuel per gallon, cents	25	27
Cost of fuel per hp-hr., cents	3.05	2.94

The thermal efficiencies and costs per hp-hr. have been calculated by the author and the resulting figures show a decreased cost of 3 per cent in favor of the motor benzol. This percentage is hardly greater than the experimental error, and inappreciable for practical

Abstract of an address delivered before the Baltimore Section of The American Society of Mechanical Engineers, April 11, 1923.

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purposes. Had the differential of cost between gasoline and the blended fuel been three cents instead of two, the costs per hp-hr. would have been exactly equal. Some of these blended fuels sell at an even greater advance in price than three cents.

The London General Omnibus Company, during the war, kept records of mileage on gasoline versus a blend of 50 per cent benzol and 50 per cent alcohol. These records showed in favor of gasoline in the proportion of a little more than seven to six, and the discrepancy for the blend was more marked in the winter, probably because of the high latent heat of alcohol causing a defective vaporization under low-temperature intake air.

The author has made systematic measurements of mileage per gallon, covering long periods of time, with different blended fuels on the local market, these measurements being made in the operation of a car for personal use. None of these measurements (admittedly inconclusive by themselves) showed an appreciable advantage gained by using blended fuel, *except with a heavily carbonized motor.*

Report No. 47, previously quoted, also states results showing that although the fuel consumption with the alcohol-benzol blend was 12 per cent better than that with gasoline on a weight basis, it was exactly the same with both fuels on a volume basis. The cost of the blended fuel is therefore greater, since the price per gallon is greater.

Operation

Concerning carbon deposits, the carbon from benzol is of softer quality than that from gasoline. The greater volatility of the blended fuel, as shown by its distillation curve, is a factor in its favor in this particular, especially in winter operation. There are no exact comparative data upon the mileage of a motor before carbon must be removed. Laboratory tests in this respect are misleading and road tests inexact.

Benzol is a very smooth-burning fuel and, when mixed with gasoline in as small quantities as 20 per cent, will suppress preignition knocks. This is particularly true of a heavily carbonized motor. This effect may in part be attributed to the higher inflammation point of benzol. It is very generally known that a benzol blend will give a smoother operation, more power, and greater flexibility in a motor carbonized enough to cause preignition with gasoline. It appears also that benzol mixtures exhibit less than straight gasoline the phenomenon of detonation.

Concentrated benzol dissolves shellac, and for this reason is not adaptable to engines with cork-float carburetors. However, commercial benzol-gasoline mixtures may be obtained which contain a comparatively small proportion of benzol and which will not injure the float coating. There has also been some uncertainty concerning the action of these mixtures on tanks and other metallic parts, some testimony indicating that corrosion is caused. It appears, however, that if the blend is properly prepared, this difficulty may be eliminated. This is true also of alcohol mixtures.

As for flexibility, or that vague quality referred to as "pep," within the author's experience there seems to be little preference with a normal motor well designed for a fair grade of gasoline. The same may be said about ability to "start cold" in winter.

It is pertinent, in this comparison, to call attention to the recent finding of the Bureau of Standards, after a wide survey, to the effect that the gasoline now produced in the United States is a better and more volatile fuel than it was two years ago.

Overall Economy

The real criterion of the utility of a fuel is the total cost of operation per mile, including cost of fuel, carbon removal, valve grinding, lubrication, and similar items of upkeep as well as deterioration; always provided the fuel satisfies the requirements of service. All considerations of cost may be swept aside if a fuel is manifestly superior in starting, accelerating, and reliability and, in short, gives the best motor operation. These qualities are as difficult to assess in money value as they are to measure in units of mass, space, or time. The fuel manufacturer is apt to overcapitalize them, and the psychological reaction upon the consumer makes him willing to pay a higher price differential than is commensurate with actual increase of mileage per dollar of operating cost, plus increase of actual serviceability.

As far as the economy item alone is concerned, it has not been conclusively demonstrated that any blended fuel on the market is superior to good gasoline, at prevailing prices. If gasoline increases to 50 cents a gallon, an alcohol-benzol-kerosene mixture, high in alcohol, would have commercial possibilities.

The author's own conclusion is that blended fuel is worth perhaps two cents more per gallon, but a price differential of three to five cents is not justified by the advantages gained.

Relief of Gasoline Shortage

The bugaboo of high-priced fuel due to the exhaustion of petroleum resources has frequently been raised, but as frequently new petroleum fields have been discovered. At present, in the United States, the situation is good. However, there must be a limit, the approach of which will some time be felt. Anything, therefore, which will defer this time must be looked upon with favor. Benzol, alcohol, or any blend for gasoline will make the present supply of petroleum go further. On the other hand, no great effect can be felt from the visible supply of benzol. It has been stated on good authority that if all the bituminous coal annually used in the United States were coked in by-product ovens, the benzol recovered would not amount to more than 25 per cent of the gasoline used in the United States. This seems inconsiderable, but if the economic pressure for good motor fuel results in some reduction of our enormous wastes of the potentialities of coal tar, blended fuels must be looked upon with increased favor. The possibility of petroleum shortage does not alarm the author, but general waste of utilities does. Gasoline may give out, but the possibilities of shale oil, lignite, and even synthetic fuels remain. Come what may, the author is confident that American engineers and chemists will meet the liquid-fuel situation with satisfaction to all concerned.

The Use of Acetone in Composite Engine Fuels

ACETONE is a clear, mobile liquid having an agreeable odor and a peppermint-like taste. It is inflammable and burns with a white smokeless flame. Concentrations of acetone vapor with air up to 2.3 per cent will not flash. Above this point there is a slight flash, increasing to and reaching a maximum violence at a concentration of 5.5 per cent of acetone vapor, and settling down to a quiet flame at 10.2 per cent. It has a boiling point of 56.5 deg. cent., or approximately 133 deg. fahr., and is miscible in all proportions with the various fuels used in motor cars. The comparative heating values of acetone and ethyl alcohol are as follows:

	B.t.u. per lb.	B.t.u. per gal.
Acetone	13,476	89,477
Ethyl alcohol	13,028	85,985

Acetone is an excellent engine fuel and in fact approaches the ideal in a number of its properties. Its low boiling point and the resulting high vapor pressure at ordinary temperatures facilitate the starting of the engine. Its homogeneity permits uniform evaporation and distribution, and, therefore, it is conducive to smooth running. Its low freezing point, —94.6 deg. cent (—138.3 deg. fahr.), prevents its solidification at the coldest winter temperatures.

Acetone will not detonate and can be used in an engine with a compression ratio as great as 7 to 1, or with a compression pressure up to 180 lb. per sq. in. It burns with a smokeless flame, does not deposit carbon in the cylinder, and, as far as can be ascertained, has no corrosive action on the cylinder or the various parts of the car with which it comes into contact.

Acetone is an excellent blending agent in reducing detonation. It is miscible in all proportions with all the liquid fuels used in motor cars, and in many instances the addition of a small percentage of acetone combines two immiscible liquids into a homogeneous solution. When it is added in small amounts to heavy hydrocarbon fuels, it minimizes the deposition of carbon and tends to prevent "fuel knocks."

Acetone is the most economical solvent of acetylene and, if saturated with this gas and added to composite engine fuels, will produce a smoother-running mixture, facilitate starting, and permit running on a leaner mixture.—R. F. Remler in the *Journal of the Society of Automotive Engineers*, July, 1923, pp. 23–24.

Endurance-Test Data and Their Interpretation

By K. Heindlhofer,[1] and H. Sjövall,[2] Philadelphia, Pa.

The determination of the endurance of different products is a subject that hitherto has been neglected, yet it is important. It is a general characteristic of products of nature as well as of manufactured products that their life varies within wide limits, and it is thus impossible to judge the life of a certain type of product by a single observation.

The average life determined by repeated endurance tests is a valuable characteristic of comparison as it shows the general magnitude of life, but taken alone it is insufficient to define durability. It must be amended by a second quantity expressing the dispersion or range of variation of the individual lives, which is an indication of reliability. Since the number of available test data is limited its average is approximate, and its precision will depend on the number of data.

The object of the authors in preparing this paper was to develop methods for computing the probable error of the average life of an object or product, depending on the number of repeated tests. This error is a measure of the reliability of the average. The results are presented in the form of a diagram which shows this probable error at a glance. Finally, it is suggested that endurance curves may be employed to determine whether an elimination test will be advantageous in the case of products made in quantity.

The life of all objects, and especially that of machine parts, varies widely. This is a general characteristic and applies even to objects which apparently are identical, i.e., made in the same factory from the same material, and are used or tested under identical conditions. It is not the authors' intention to investigate the cause of this variability, but rather to represent and to interpret the life or endurance of such objects by figures which may serve as a basis of comparison when the selection or application of machines or machine elements is under consideration.

It is customary to express capacity or performance by figures. We speak of the horsepower of a motor, the watt consumption of a lamp, the gallons-per-minute capacity of a pump, these figures indicating whether the machine in question is suitable for the purpose or worth the price; and it would be equally valuable if we could express how long a gear, a bearing, or a die would stand up under given conditions.

It is not customary to specify life data on machines. This is partly due to the great difficulty and expense of acquiring such data, and partly to the wide discrepancy generally found between results when endurance tests are conducted by two independent parties. In such cases the degree of carefulness exercised in the tests is usually questioned and the testing machines and arrangements are blamed; but granting this, the lack of agreement is mostly due to the variable nature of such data, even if all the conditions are uniform. The discrepancy is due to the inherent variability of endurance in general.

A Method of Interpreting Endurance Data

In spite of this difficulty it is possible to derive endurance figures having a comparative value. This may be achieved by collecting a great number of endurance data on products of the same type and size, tested under identical conditions, and arranging the lives in an ascending sequence, the cumulative number of individuals being the ordinates and the lives the corresponding abscissas. Examples taken from actual observations are shown in Figs. 1, 2, and 3. These graphs are called "cumulative frequency curves."

It is advantageous to standardize the total length of the ordinate, calling it 100 per cent, and subdivide it as shown in Fig. 4. One hundred per cent would then mean the whole number of individual objects tested. It is easy to pick from the diagram the percentage of all the objects tested which have a life longer (or shorter) than a given number of hours, revolutions, or other units. This idea is illustrated in detail in Fig. 4 and Table 1.

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[2] Research Engr., S. K. F. Industries.

Presented at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, of The American Society of Mechanical Engineers. All papers are subject to revision.

In order to be able to obtain these percentages with a sufficient degree of accuracy, an extensive collection of data is required. The number in each interval, say, between 10 and 20 per cent, must be considerable. Such, however, is seldom the case, for the expense of testing often forbids the collection of more than 10 or 20 data. Such a limited number cannot be split up into intervals upon the content of which dependence can be placed, therefore it is preferable to choose a characteristic which is a resultant of all the values available. The average or mean of all the values conforms to this requirement, and at the same time it is readily derived and its meaning simple. In many cases knowledge of the average life is sufficient. For example, when a large plant or a city has to be illuminated by incadescent lamps, the cost of replacing the lamps may be determined from the average life of the lamps.

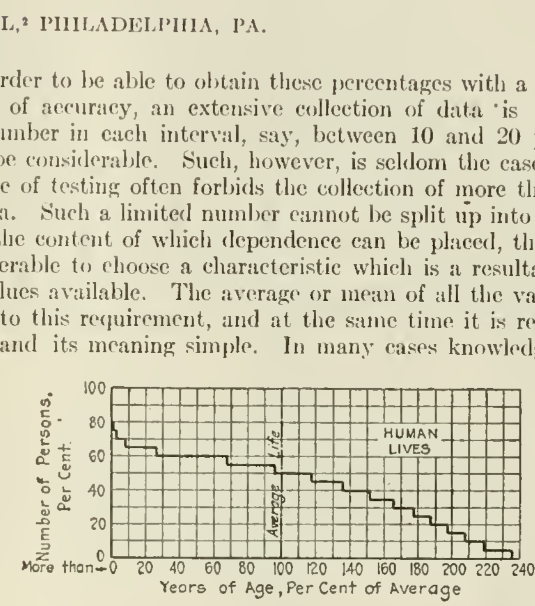


Fig. 1

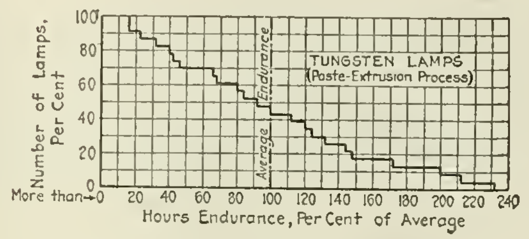


Fig. 2

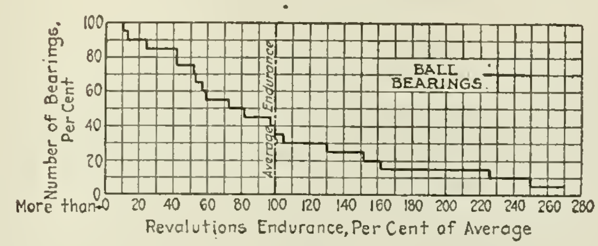


Fig. 3

Figs. 1–3 Examples of Endurance Data Plotted in the Form of Cumulative Frequency Curves

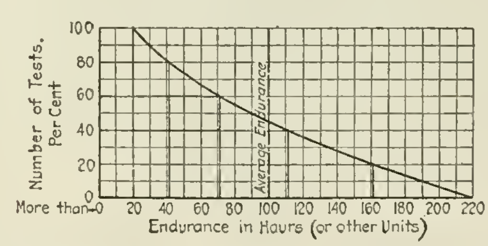


Fig. 4 Representation of Numerous Test Data Obtained Under Identical Test Conditions

Table 1 Representation of Test Results Plotted in Fig.

Percentage of total number of test objects	Endurance in hours, revolutions, or other units, more than
100	20
90	29
80	41
70	55
60	71
50	90
40	111
30	135
20	161
10	189
0	220

However, there are other cases where the average alone, while important, is insufficient to enable one to judge of the merit of the product. All the elements of construction from which a high degree of reliability is expected must show as small a fluctuation in endurance as possible. For example, the material of a given part of an airplane should, in addition to a high average, show as little fluctuation as possible. Thus the deviations from the average must not be too great. This requirement would exclude extremely weak specimens.

From this it follows that at least two characteristics, the average life and the variation of lives, are required to define endurance. The difference between the two is best illustrated by the examples presented in Figs. 5 and 6, which show two cumulative curves with identical averages but with different ranges of individual lives. This range or "dispersion" may best be expressed by the

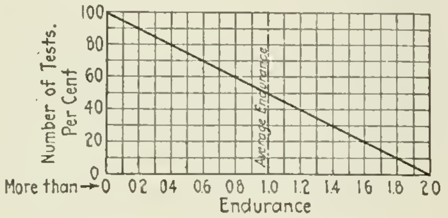


Fig. 5

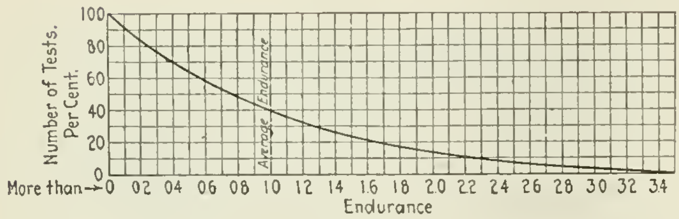


Fig. 6

Figs. 5 and 6 Endurance Figures of the Same Average but of Different Dispersions

"root-mean-square deviation" of lives from the average, because this value is mainly determined by large deviations. The root-mean-square deviation is obtained by finding the sum of the squares of individual deviations from the mean, dividing this sum by the number of individuals, and extracting the square root.

When introducing the average from a small number of tests which vary between wide limits, a further question arises, namely, how reliable is this value? To answer this question, select, say, 10 data at random from an extensive collection, determine their average, and repeat this process many times. When inspecting the large number of averages thus obtained it will be found that their frequency of occurrence will be greater near the mean of the *whole* collection, and that only a few will be found which deviate greatly from the total mean. Two factors govern their distribution. The

TABLE 2 DATA OF CUMULATIVE FREQUENCY CURVE USED IN EXPERIMENT ON VARIABILITY OF AVERAGE OF ENDURANCE VALUES (SEE FIG. 6)

Total average endurance of an infinite number of tests = 100
Root-mean-square deviation from average = 83.9

Endurance values in 50 intervals				
2	26	60	102	174
4	29	64	108	184
6	32	68	114	195
9	35	72	119	207
11	38	76	125	219
14	42	80	132	234
16	45	84	139	251
18	48	89	146	274
21	52	93	154	301
24	56	98	163	347

first is the number of data (in the present example 10) included in a group, and the second the dispersion or range of the individual values in the original collection. It is obvious that a more homogeneous collection (Fig. 5) yields group averages lying close together, while the opposite is the case with less homogeneous data (Fig. 6).

For the underlying purpose of the work it would be convenient to set limits within which a given percentage of all possible group averages would be located. Other things being equal, the closer the specified limits, the smaller the percentage of group averages within those limits. This statement may also be expressed in another way: the narrower the limits, the smaller the probability of the appearance of average values within them.

The law governing limits when a limited number of data of known dispersion are available, will be illustrated first by an example. The deduction of this law is given later in the paper.

Assume that a not too small number of data have been obtained and tabulated (Table 2), and which, when graphically presented, appear as shown in Fig. 6. Their average value is 100. The root-mean-square deviation from the average is

$$\mu = \sqrt{\frac{98^2 + 96^2 + 94^2 + 91^2 + \ldots}{50}} = 84$$

It is now possible to determine the limits $\pm\Delta$ within which the average value of a limited number of tests on the same product will be located with a probability of, say, 50 per cent. The procedure to determine the limits for any other value of the probability, such as 90 per cent or even 99 per cent, would be similar.

The logarithmic chart forming Fig. 7 renders the computation simple. First the number of test data is located on the lower bounding line of the chart. Let this number be $n = 10$. The intersection of the ordinate of $n = 10$ with the line $P = 0.50$ (i.e., probability = 50 per cent) gives the value $\pm\Delta/\mu = 0.213$. Since the root-mean-square deviation μ is equal to 84, $\pm\Delta = 0.213 \times 84 = 18$. This means that the probability is 50 per cent that the average life of 10 tests is within the limits of 100 ± 18. The probable error is thus ± 18. Fig. 9 shows these limits.

A second example is shown in Fig. 8, where $n = 10$ and $\mu = 58$.

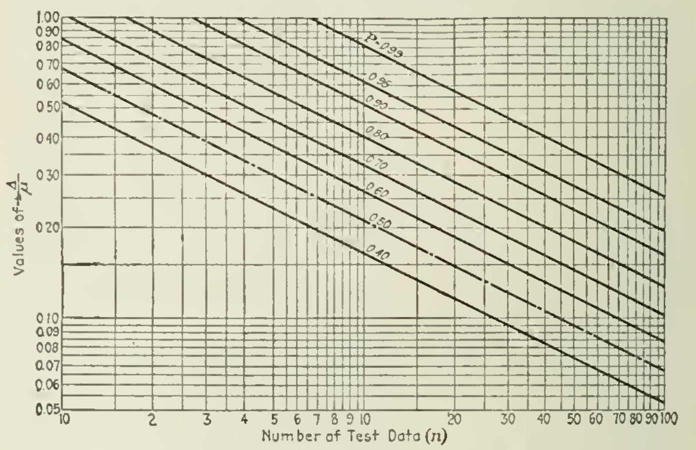


Fig. 7 Diagram of Probability of Average Within Limits

(n = number of objects whose average is taken; μ = root-mean-square deviation from average; Δ = limits of the average; P = probability that average is within $\pm\Delta$.)

The average is 100 ± 12 at 50 per cent probability. A comparison of Figs. 8 and 9 shows the influence of the dispersion on the limits.

The probability may be visualized. Imagine the test series repeated a great number of times. Each series has a different average. In case of the 90 per cent probability, 90 per cent of all the averages would lie inside the limits and 10 per cent outside. In other words, the chances that the average of any of the series will lie inside the limits are 9 to 1. Similarly, the 50 per cent probability represents equal chances, for which reason the magnitude between the limits is called the probable error.

Verification of the Proposed Method

The procedure for determining the probable error of the average, and the more general case of setting limits which include the average at any desired probability, having been described, it remains to be shown how the values used in plotting Fig. 7 were obtained.

From the theory of least squares it is known that the probability P of an error $\pm\Delta$ of the average value of n observations may be expressed by the formula

$$P_{\pm\Delta} = \frac{2}{\sqrt{\pi}} \int_0^{\frac{\sqrt{n}}{\sqrt{2}}\frac{\Delta}{\mu}} e^{-t^2} dt \ldots\ldots\ldots\ldots\ldots [1]$$

where μ is the root-mean-square deviation. This formula has been derived under the assumption that the errors of individual observations occur at random, i.e., that they follow Gauss's law of frequency of error.

Fig. 7 is based on Formula [1] and is constructed as follows: The number of tests n and Δ/μ are arbitrarily assumed, thus determining the upper limit of the integral. The integral may then be evaluated by tables found in handbooks. The corresponding values of Δ/μ, n, and P may then be plotted, preferably on logarithmic paper.

It remains to be shown, however, that Formula [1] is applicable with sufficient accuracy to cumulative frequency curves (Figs. 1, 2, 3, and 4) which do not necessarily follow Gauss's law.

TABLE 3 EXPERIMENT ON THE VARIABILITY OF THE AVERAGE VALUE OF A LIMITED NUMBER OF DRAWINGS

(Each score is the average of 10 drawings from the numbers given in Table 2)

Percentage of ideal average	Distribution of 250 scores							
0 to 10	0							
10 to 20	0							
20 to 30	0							
30 to 40	1							
40 to 50	1							
50 to 60	11111	11						
60 to 70	11111	11111	11111	1				
70 to 80	11111	11111	11111	11111	11111	1111		
80 to 90	11111	11111	11111	11111	11111	11111	1111	
90 to 100	11111	11111	11111	11111	11111	11111	111	
100 to 110	11111	11111	11111	11111	11111	11111	11111	11
110 to 120	11111	11111	11111	11111	11111	11111	11	
120 to 130	11111	11111	11111	11111	11111	1		
130 to 140	11111	11111	11111	1				
140 to 150	11111	111						
150 to 160	11111							
160 to 170	1111							
170 to 180	1							
180 to 190	0							
190 to 200	0							

A general proof based on the symbolic method appears to be difficult because the shapes of the cumulative curves are arbitrary. For the purpose in hand it was considered sufficient to apply Formula [1] to two cumulative curves which represent typical conditions such as obtain in practice. In order to broaden the limits of the proof, extreme conditions have been chosen.

In the first example a cumulative curve is assumed the asymmetry of which with respect to the average is pronounced (Fig. 6 and Table 2). The endurance values which define this curve were derived from actual test series. In the second example the curve is a straight line (Fig. 5). This symmetrical distribution corresponds to the so-called problem of De Moivre.[1]

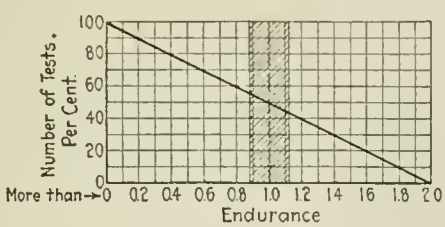


Fig. 8

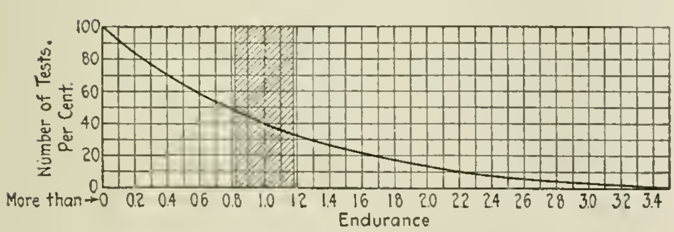


Fig. 9

Figs. 8 and 9 Limits Including 50 Per Cent of All Possible Averages of 10 Values Picked at Random from the Cumulative Frequency Curves of Figs. 5 and 6

The proof consists in computing the probabilities by a method the correctness of which cannot be questioned. These values are then to be compared with those derived by using Formula [1], when the comparison will bear out any possible discrepancy. While for the first example an experimental method was used, the second was calculated according to a rigorously correct formula.

The experimental procedure was as follows: The figures given in Table 2 were printed on small wooden disks and collected in an urn. A disk was drawn therefrom and its number recorded. This disk was then returned and the contents of the urn were thoroughly and systematically mixed to insure a random appearance of the disks. The procedure was then repeated a great number of times (2500). Figures thus obtained were arranged in groups of $n = 10$ in the sequence they appeared. Each group was averaged and the results arranged as in Table 3. The frequency of average within a certain interval may be found from this tabulation. The probabilities thus obtained and the corresponding values calculated by using Formula [1] are compiled in Table 4.

TABLE 4 VERIFICATION OF FORMULA [1] FOR 10 DRAWINGS

(a) Straight Line, Fig. 5 (Root mean square = 0.577; average = 1.000)

Δ = Limit on either side of the average	Probability: Calculated according to Formula [1] or Fig. 7	Probability: Mathematically correct values
±0.1	0.416	0.412
0.2	0.727	0.722
0.3	0.900	0.900
0.4	0.967	0.973
0.5	0.994	0.995
0.6	0.999	0.999

(b) Cumulative Frequency Curve, Fig. 6 (Root mean sq. = 0.893; avg. = 1.000)

Δ = Limit on either side of the average	Probability: Calculated according to Formula [1] or Fig. 7	Probability: Experimentally determined from 250 scores at 10 drawings. (See Table 3)
±0.1	0.294	0.280
0.2	0.549	0.544
0.3	0.742	0.764
0.4	0.868	0.892
0.5	0.940	0.952
0.6	0.976	0.976
0.7	0.992	0.996
0.8	0.997	1.000
0.9	0.999	1.000

In case of the straight-line distribution (Fig. 5) the probabilities for given limits and 10 tests per group were calculated from De Moivre's formula. These figures are also entered in Table 4 with corresponding values calculated from Formula [1].

The agreement between the corresponding figures is satisfactory, justifying the approximation involved in the use of Formula [1], which serves to determine the limits of averages such as those derived from endurance-test data. The agreement would be still better for $n>10$, while for $n<10$ the accuracy would necessarily be lower.

Improving the Endurance of Quantity Products by Elimination Tests

In addition to their function of gaging quality and reliability, cumulative endurance curves may be applied in a constructive manner. Imagine a quantity product having a cumulative frequency curve like that of Fig. 1. It is evident that this product would be considerably improved by subjecting it to an endurance test resembling service conditions for about one-tenth of the time of the average life before the product left the factory. By this procedure 35 per cent would be eliminated, improving the average of the remainder by approximately 50 per cent.

An improvement is not always effected by running all articles through such a test. For example, the products dealt with in Figs. 2 and 3 would lose in value by this process.

A judgment as to whether an elimination test will be advantageous or not can only be based on a careful study of cumulative endurance data.

Conclusions

There are three characteristic figures which define the endurance quality of a product:

(1) The average life, which shows the general magnitude of life

(2) The dispersion or root mean square, which expresses reliability of the *product* itself

(3) The probable error of the average. This indicates the reliability of the *average;* in other words, it shows whether or not the test has been repeated a sufficient number of times.

Discussion

FOLLOWING its presentation Mr. Heindlhofer, in reply to questions put to him, elaborated several of the statements made in the paper. If, for example, he said, a crankshaft were put in an automobile engine and run under test it would break

(Continued on page 625)

[1] E. Czuber, Wahrscheinlichkeitsrechnung, 3d ed., pp. 63–66, Leipsic; B. G. Teubner.

Bending Stresses in Curved Tubes of Rectangular Cross-Section[1]

By S. Timoshenko,[2] East Pittsburgh, Pa.

In this paper the author analyzes the stresses in bent tubes of rectangular cross-section and shows that in the case of thin tubes the distortion due to bending results in greater flexibility and less strength than given by the usual formulas. In an appendix to the complete paper an approximate solution of the problem is obtained by a consideration of the potential energy of deformation.

The bending of curved tubes is accompanied by a distortion of the cross-section. As a result of this distortion thin tubes are more flexible and have less strength than given by the usual formulas. In one example of a Fairbairn crane, considered later, the maximum stress is 67 per cent greater than the value given by the ordinary formula for the bending of curved bars.

This paper will consider the case of the bending of a tube under the action of moments M only. Referring to Fig. 1, if the dimension a of the cross-section is small in comparison with the radius of curvature R of the tube, the maximum stress and the increase of the angle α are usually calculated by the formulas

$$p_{max} = \frac{aM}{2I} \qquad [1]$$

$$\Delta\alpha = \alpha\frac{MR}{EI} \qquad [2]$$

where E denotes the modulus of elasticity and I the moment of inertia of the cross-section about the neutral axis.

In the case of a solid cross-section these formulas are sufficiently accurate, but in the case of a tube the problem is more complex. The forces of tension acting on any element ss_1 (Fig. 1) and the forces of compression acting on any element rr_1 give resultants whose direction is toward the neutral axis. These forces produce the distortion of the cross-section shown in Fig. 1 (b).

Assuming that the cross-sections of the tube remain plane on bending, the conclusion follows that the elongation e of any element ss_1 will depend not only on the increase $\Delta\alpha$ of the angle α, but also on the radial displacement w due to the distortion of the cross-section.

Let $s's_1'$ represent the position of the element ss_1 after deformation [Fig. 1 (a)]. It is seen that the extension ls_1' of the element can be represented by

$$ls_1' = ks_1' - kl$$

The first term on the right-hand side of this equation, due to rotation of the cross-section s_1r_1 about the neutral axis X, is equal to $\frac{\Delta\alpha a}{2}$; w is assumed to be small in comparison with a. The second term, due to radial displacement w, is equal to $w\alpha$. Substituting this value in the equation and dividing it by $R\alpha$, the initial length of the element ss_1 (a assumed to be small in comparison with R), the following expression is obtained for the longitudinal strain of the element ss_1:

$$e = \frac{\Delta\alpha a}{2R\alpha} - \frac{w}{R} \qquad [3]$$

Formula [3] may also be used in calculating the compression of any element rr_1. It is seen that as a result of the distortion of the cross-section, the stresses at the middle of the plates mn and qt become less than those given by Formula [1]. This decrease of stresses in the central portions of mn and qt will necessarily be associated with an increase of stresses in other parts of the cross-section.

The true values of the maximum stress and of the increase of the angle α may be obtained by using Formulas [1] and [2], if for I there be substituted a smaller quantity

$$I_1 = \beta I \qquad [4]$$

where the coefficient β, less than unity, is to be calculated by the following formula:

$$\beta = 1 - 2\Lambda \times \frac{12(1-\sigma^2)\left[2 + \frac{1}{2}\frac{b}{a}\left(\frac{h_2}{h_1}\right)^3\right]^2}{\pi^2\left(1+\frac{i_2}{i_1}\right)\left[\pi^4 + 4\pi^2\frac{b^2}{a^2}\left(\frac{h_2}{h_1}\right)^6 + \frac{40}{3}\pi^2\frac{b}{a}\left(\frac{h_2}{h_1}\right)^3\right] + 12\Lambda(1-\sigma^2)\pi^2\left(1+\frac{i_2}{i_1}\right)\left[1 + \frac{3}{4\pi^2}\frac{b^2}{a^2}\left(\frac{h_2}{h_1}\right)^6 + \frac{16}{3\pi^2}\frac{b}{a}\left(\frac{h_2}{h_1}\right)^3\right]} \qquad [5]$$

where

h_1 = thickness of horizontal plates mn and qt
h_2 = thickness of vertical plates mq and nt
i_1 = moment of inertia about neutral axis of the horizontal plates
i_2 = moment of inertia about neutral axis of the vertical plates
σ = Poisson's ratio of the material (in these calculations $\sigma = 0.3$)

and

$$\Lambda = \frac{b^4}{R^2h_1^2} \qquad [6]$$

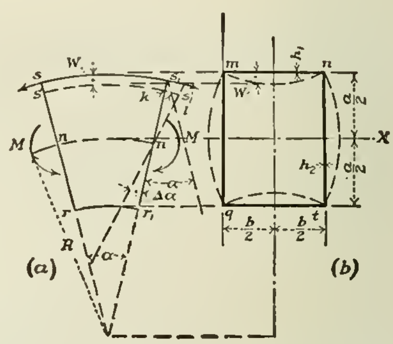


Fig. 1 Section of Bent Tube of Rectangular Cross-Section

In the case of a tube of square cross-section and of a constant thickness h,

$$a = b;\; h_1 = h_2 = h$$

$$\frac{i_2}{i_1} = \frac{ha^3}{6} : \frac{ha^3}{2} = \frac{1}{3}$$

and from Formula [5],

$$\beta = \frac{49.18 + 1.332\Lambda}{49.18 + 3.232\Lambda} \qquad [7]$$

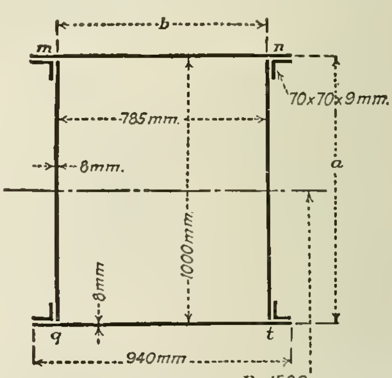


Fig. 2 Cross-Section of Fairbairn Crane Box Girder

The effect of distortion of cross-section depends on the magnitude of the quantity Λ. If Λ is small, i.e., in the case where the radius R and the thickness h are large, the coefficient β will be nearly unity and Formulas [1] and [2] will give sufficiently accurate results. Taking another extreme case and putting $\Lambda = \infty$ in [7], $\beta = 0.412$. In this case the maximum stresses and the flexibility of the tube are about 2.5 times greater than the values given by Formulas [1] and [2].

As an example, take $\frac{R}{a} = 10$; $\frac{a}{h} = 50$. Then, from [6], $\Lambda = 25$, which, substituted in [7], gives $\beta = 0.513$. The maximum stresses in this case will be about twice as great as given by Formulas [1] and [2].

(Continued on page 612)

[1] The case of tubes of circular cross-section has been considered by Prof. Th. Karman. See *Zeit. Ver. Deutsch. Ing.*, 1911, p. 1889.

[2] Research Dept., Westinghouse Elec. Mfg. Co.

Presented at the Spring Meeting, Montreal, Canada, May 28 to 31, 1923, of The American Society of Mechanical Engineers. Abridged by omission of appendix. All papers are subject to revision.

The Strength of Bolt Threads as Affected by Inaccurate Machining[1]

Results of Experiments Conducted at the Bureau of Standards to Determine the Effect of Variations in the Pitch-Diameter Clearance and the Face Angle of the Nut on the Tensile Strength—Effect of Materials Used

By GEORGE M. DEMING,[2] SEATTLE, WASH.

THE National Screw Thread Commission, created by Act of Congress (H. R. 10852) approved July 18, 1918, for the purpose of ascertaining and establishing standards for screw threads for the use of the various branches of the Federal Government and for the use of manufacturers, have recommended a system of threads in their Progress Report dated January 4, 1921.[3] This report describes the threads approved by the commission and gives information, data, and specifications pertaining to their manufacture.

The strength of screw threads did not receive particular attention by the Commission, but their Research Committee[4] proposed a preliminary experimental program to determine the effect of extreme inaccuracies in machining which sometimes occur in commercial work. At its request the Bureau of Standards undertook the experimental work, using the test specimens supplied by the Committee.

Description of the Test Specimens

There are many variations both in the material and the dimensions of commercial bolts and nuts. Many of these, however, have little influence upon their strength or usefulness.

Differences in the fit of the nut on the bolt are obtained by varying the pitch-diameter clearance between the bolt and nut.

Four classes of screw-thread fits, with subdivisions, were established by the Commission. These are

- Class I, loose fit
- Class II, medium fit: A, regular; B, special
- Class III, close fit
- Class IV, wrench fit: A for light sections, B for heavy sections.

The strength of the threads under axial loading should increase from Class I, loose fit, to Class IV, wrench fit. In order to determine the effect on strength due to differences in fit the specimens marked 4-A and 4-B were tested. The threads on the internal member were all of the same size and the variations in clearance were obtained by tapping the nuts oversize. This method differs from that adopted by the Screw Thread Commission in their report. They recommend that differences in fit be obtained by variations in the pitch diameter of the screw. The dimensions and other data for these specimens are given in Table 1. It will be noted that the dimensions of these threads, in most cases, do not come within the limits established by the Commission, but it is believed that the effect of the measured pitch-diameter clearance on the strength does not depend upon close adherence to these standards.

The strength of the thread also depends upon the proper bearing of the face of the nut. If the face is not perpendicular to the axis of the screw, bending of the screw will occur when load is applied and the strength of the thread will be decreased.

To determine the effect of this eccentric loading, the specimens marked 5-A, 5-B, and 5-C were tested. The dimensions and other data for these specimens are given in Table 2.

The material for each group of specimens was the steel often used in commercial work with those threads. No data are available regarding the physical properties of these materials. All the screws were very carefully threaded with a die, the same die being used for all similar specimens. All nuts were very carefully tapped, using the same tap for all to have the same fit. Three screws and nuts for each fit were prepared and one of each measured at the Bureau of Standards.

Method of Testing

All the bolts were loaded in tension, using a Riehlé testing machine having a capacity of 50,000 lb. The nut was held by the stationary head of the machine and the load applied to the bolt by the moving head. A dial micrometer attached to the nut was used to measure

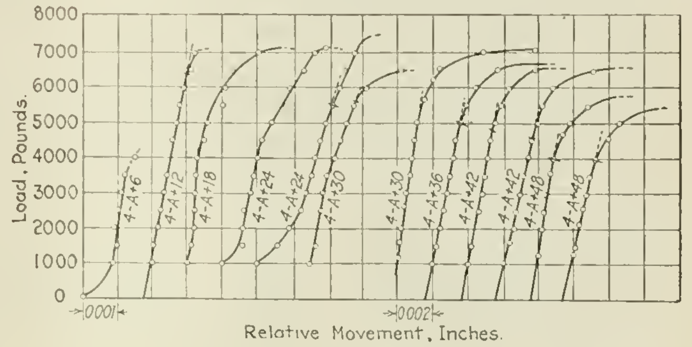


Fig. 1 Load Graphs for Specimens 4-A, National Coarse-Thread Series—Clearance

(Scale for relative movement for Specimens Nos. 4-A+36 to 4-A+48 is 0.002 in.)

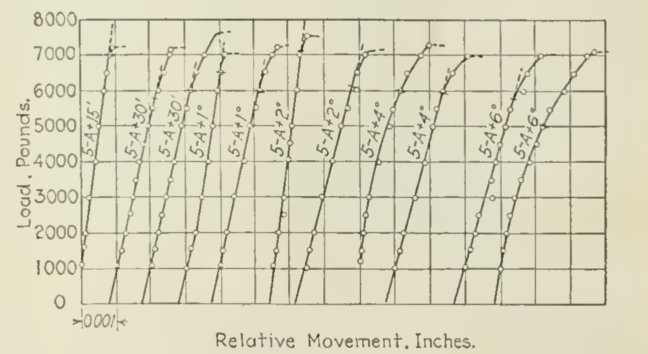


Fig. 2 Load Graphs for Specimens 5-A, National Coarse-Thread Series—Face Angle

the movement of the screw with respect to the nut. This instrument was graduated to 0.0001 in., and tenths of a division could be readily estimated.

The movement was read for load increments of 500 lb. until the yield point was reached. Load graphs were then drawn, from which the proportional limit was determined. Figs. 1 and 2 give these graphs for two series of tests.

The yield point was found by the "drop of the beam" of the testing machine and by the very rapid increase in the movement shown by the dial micrometer. The yield point was well defined in all the specimens.

The ultimate strength, in most cases, was not determined as the failure of the thread was studied by cutting away both nut and screw to an axial plane. Characteristic failures are shown in Fig. 3.

Results of the Tests

The results of the tests are given in Tables 1 and 2 and in part in the load graphs Figs. 1 and 2.

Inspection of the load graphs shows, as might be expected, that

[1] Published by permission of the Director of the Bureau of Standards of the U. S. Department of Commerce.

[2] Instructor, Pacific Telephone & Telegraph Co.'s Plant School.

[3] No. 42, Miscellaneous Publications of the Bureau of Standards.

[4] The members of the Research Committee were E. H. Ehrman, Chairman, Maj. O. B. Zimmerman, and Commander S. M. Robinson.

TABLE 1 STRENGTH OF BOLT THREADS UNDER AXIAL LOADING

Specimens 4-A—National Coarse-Thread Series

(Screws and nuts, open-hearth cold-rolled steel; lead error of screw, +0.0026 in. in 10 threads)

Specimen No.	Tap Used for Nuts (3/8 in. 16 thd. U.S. Std.) Size, pitch diam. plus	Make	Measured Dimensions — Nut — Minor diam., in.	Nut — Pitch diam., in.	Screw — Major diam., in.	Screw — Pitch diam., in.	Pitch-diameter clearance, in.	Tensile Test — Proportional limit (av'g), lb.	Tensile Test — Yield point (av'g), lb.
4-A + 0	......	Regular	0.319	0.351	0.373	0.336	0.015	..	7090
4-A + 6	0.006 in.	Special	0.318–0.320	0.359–0.361	0.373	0.336	0.023–0.025	3500	7100
4-A + 12	0.012 in.	Special	0.322	0.358	0.373	0.336	0.022	6400	7150
4-A + 18	0.018 in.	Special	0.325	0.361	0.373	0.336	0.025	4000	7270
4-A + 24[1]	0.024 in.	Special	0.334	0.361	0.373	0.336	0.025	5000	7340
4-A + 30	0.030 in.	Special	...	0.364	0.373	0.336	0.028	5600	6645
4-A + 36[2]	0.036 in.	Special	...	0.372	0.373	0.336	0.036	5050	6930
4-A + 42[3]	0.042 in.	Special	...	0.377	0.373	0.336	0.041	4700	6645
4-A + 48[4]	0.048 in.	Special	...	0.385	0.373	0.336	0.049	4000	5655
Basic Dimensions, Screw Thread Com.....			0.2938	0.3344	0.375	0.3344			
Specimens 4-B—National Fine-Thread Series									
(Screws, 3 1/2 per cent nickel steel, heat treated; nuts, open-hearth cold-rolled steel; lead error of screw, −0.0015 in. in 15 threads)									
	(3/8 in. 24 thd. S.A.E. Std.)								
4-B + 0	......	Regular	0.339	0.366	0.376–0.380	0.351–0.352	0.015	8000	10745
4-B + 4	0.004 in.	Special	0.343	0.373	0.376–0.380	0.351–0.352	0.022	7000	10796
4-B + 8	0.008 in.	Special	0.344–0.350	0.375	0.376–0.380	0.351–0.352	0.024	7200	10100
4-B + 12[5]	0.012 in.	Speical	0.345	0.376	0.376–0.380	0.351–0.352	0.025	6550	9273
4-B + 20[6]	0.020 in.	Special	0.342	0.377	0.376–0.380	0.351–0.352	0.026	6233	8000
Basic Dimensions, Screw Thread Com.....			0.3209	0.3479	0.3750	0.3479			

[1] In one test (yield point 7500 lb.) bolt broke. [2] In one test (y. p. 7100 lb.) bolt broke near head. [3] In one test (y. p. 6600 lb.) nut yielded. [4] In one test (y. p. 5850 lb.) nut yielded. [5] In one test (y. p. 9500 lb.) thread stripped in nut. [6] In two tests (y. p. 8000 lb.) thread stripped in nut.

TABLE 2 STRENGTH OF BOLT THREADS UNDER ECCENTRIC LOADING

Specimens 5-A—National Coarse-Thread Series

(Screws and nuts, open-hearth cold-rolled steel; lead error of screw, +0.0017 in. in 10 threads; all nuts tapped with regular 3/8-in. 16-thread U. S. Standard tap)

Specimen No.	Angle of face of nut, deg.	Measured Dimensions — Nut — Minor diam., in.	Nut — Pitch diam., in.	Screw — Major diam., in.	Screw — Pitch diam., in.	Pitch-diameter clearance, in.	Tensile Test — Proportional limit (av'g), lb.	Tensile Test — Yield point (av'g), lb.
5-A + 15′	0.25	0.304	0.357	0.375	0.337	0.020	7000	7235
5-A + 30′	0.50	0.304	0.357	0.375	0.337	0.020	5900	7410
5-A + 1°	1.00	0.304	0.357	0.375	0.337	0.020	6250	7100
[1]5-A + 2°	2.00	0.304	0.357	0.375	0.337	0.020	6600	7345
5-A + 4°	4.00	0.304	0.357	0.375	0.337	0.020	6000	7150
5-A + 6°	6.00	0.305	0.356	0.375	0.337	0.019	5400	7065
Basic Dimensions, Scr. Thd. Com.....		0.2938	0.3344	0.375	0.3344			
Specimens 5-B—National Fine-Thread Series								
(Screws, 3 1/2 per cent nickel steel; nuts, open-hearth cold-rolled steel; lead error of screw, +0.0025 in. in 15 threads; all nuts tapped with regular 3/8-in. 24-thread S.A.E. Standard tap)								
5-B + 15′	0.25	0.327	0.355	0.372	0.349–0.350	0.005	8000	9650
5-B + 30′	0.50	0.327	0.355	0.372	0.349–0.350	0.005	7250	9280
[1]5-B + 1°	1.00	0.327	0.355	0.372	0.349–0.350	0.005	7600	9155
[2]5-B + 2°	2.00	0.327	0.355	0.372	0.349–0.350	0.005	5950	9340
5-B + 4°	4.00	0.327	0.355	0.372	0.349–0.350	0.005	7000	9555
5-B + 6°	6.00	0.327	0.355	0.372	0.349–0.350	0.005	7100	9770
Basic Dimensions, Scr. Thd. Com.....		0.3209	0.3479	0.375	0.3479			
Specimens 5-C—National Fine-Thread Series								
(Screws and nuts, 3 1/2 per cent nickel steel, heat-treated; lead error, +0.0024 in. in 15 threads; all nuts tapped with regular 3/8-in. 24-thread S.A.E. Standard tap)								
[2]5-C + 15′	0.25	0.329	0.358	0.371–0.373	0.347–0.349	0.010	7000	9465
[2]5-C + 30′	0.50	0.329	0.358	0.371–0.373	0.347–0.349	0.010	7150	9510
5-C + 1°	1.00	0.329	0.358	0.371–0.373	0.347–0.349	0.010	7150	9510
[2]5-C + 2°	2.00	0.329	0.358	0.371–0.373	0.347–0.349	0.010	7600	9515
[3]5-C + 4°	4.00	0.329	0.358	0.371–0.373	0.347–0.349	0.010	8550	9750
[1]5-C + 6°	6.00	0.325	0.360	0.371–0.373	0.347–0.349	0.012	8000	9595
Basic Dimensions, Scr. Thd. Com.....		0.3209	0.3479	0.375	0.3479			

[1] In one of the two tests bolt failed in thread at face of nut. [2] In both of the two tests bolt failed in thread at face of nut. [3] In one test (yield point 9480 lb.) bolt failed in thread at face of nut; in the other, nut yielded.

the curves are not as regular as those obtained from tension tests of steel specimens. The unusual irregularity of the curves for specimens 4-A+6 to 4-A+30, Fig. 1, may possibly be due to lack of experience on the part of the men making the tests. The slope of the curve is not considered significant for this work nor the fact that some of the curves are concave and some convex toward the axis of loads.

The proportional limit was taken as the load at which the curve departed from the straight line and was in nearly all cases very well defined. The decrease in the proportional limit and in the yield point as the clearance or the angle of the face of the nut are increased is clearly shown. It is probable that the yield point is, for practical purposes, the ultimate strength of the threads. This is shown by the fact that the curves are nearly horizontal at the yield point, and the sections, Fig. 3, show that little additional load could be sustained by any of the specimens except perhaps 5-C+6°. The proportional limit may be taken as the elastic limit of the screw with nut. If it is not exceeded, any relative displacement which persists after removal of the load is probably due to local crushing of the thread surfaces in contact rather than to permanent set of the material as a whole.

The movement which occurs before the yield point is reached can be estimated from the curves. For example, the movement for the clearance specimens shown in Fig. 1 for Series 4-A is about three times that at the proportional limit, while the specimens of Series 4-B moved nearly twice as far before failure. This may be due either to the material or to the size of the threads, but it suggests that fine-thread screws of heat-treated nickel steel in combination with open-hearth cold-rolled steel nuts resist abuse better than coarse-thread bolts and nuts of open-hearth cold-rolled steel. This is a matter of particular importance for bolts of small diameter, which are frequently overstrained when assembling by the use of a long wrench applied with little judgment.

The fine-thread screws are stronger than those having a coarse thread as is shown by Figs. 4 and 5, which also show the effect of clearance on the strength. The strength of the coarse threads, Fig. 4, is decreased but little as the clearance is increased. It should be noted that the depth of the thread is 0.0406 in., so that a clearance of 0.050 in. leaves only 0.0156 in. or 38 per cent of the threads engaged. In spite of this both the proportional limit and the yield point were only decreased about 25 per cent. This clearance is much greater than the 0.0144 in. for loose fits recommended as the maximum by the Screw Thread Commission, and is greater than should occur in practice.

No tests were made upon specimens having small clearances, but the curves in Fig. 4 give no indication that appreciably higher strengths would have been obtained. As, however, only 81 per cent of the thread surfaces are in contact, greater strength would be expected, particularly for the close and wrench fits. Experimental work could well be undertaken to supply information on this point.

The fine-thread nickel-steel screws show a marked decrease in strength with increase in clearance, as shown by Fig. 5. In this case there is reason to believe that screws having less than 0.015 in. clearance would show higher strengths. The smallest clearance tested is, for these specimens as well as for those having coarse threads, much greater than the 0.0105 in. recommended by the Commission. As the depth of thread is 0.0271 in., only 72 per cent of the thread surfaces are in contact if the clearance is 0.015 in., while the Commission recommends at least 91.5 per cent. The strength, especially the yield point, decreased very rapidly with an increase in clearance, this decrease for an increase in clearance from 0.015 to 0.026 (52 per cent of the thread surfaces in contact) was about 25 per cent for both the yield point and the proportional limit.

The difference in the behavior of the coarse- and the fine-thread specimens is not easily explained. If made of the same material and with the clearance in both cases proportional to the depth of the thread, it is probable that the strengths would be the same. Screws of nickel steel, heat treated, should be stronger than those of cold-rolled steel. The area to be sheared at the base of the thread, if failure occurred in that way, is much larger for the nut than for the screw, which would justify nickel-steel screws. Fig. 3 shows, however, that failure occurred by shearing or bending the thread in the nut. As the decrease in strength in each case was about 25 per cent for the greatest clearance tested, there is no very noticeable difference in this respect although the fine-thread series decreased most rapidly.

The effect of varying the angle of the face of the nut is shown in Fig. 6. The angles are in all cases so small that the screw is

apparently bent until the nut bears over the entire face without decreasing its strength. A slight decrease, as shown at 5-A, might be expected, but increases are shown at 5-B and 5-C. It should be remembered that in service in tightening the nut there is a reversal of stress in the bolt which may reduce the strength much below that found for these tests.

The amount of movement after the proportional limit is reached is the lowest for the screw and nut of open-hearth cold-rolled steel, as in the clearance tests, and the greatest for the nickel-steel screw in the cold-rolled-steel nut. The screw and nut of nickel steel appear to have a movement between these two.

Conclusions

1 The axial movement of a screw in its nut is approximately proportional to the load until a load is reached after which the movement increases rapidly.

2 The yield point shown by "drop of beam" or the rapid increase in the relative movement of the screw and nut is practically the ultimate strength of the threads.

Effect of Variation in Pitch-Diameter Clearance:

3 As the clearance increases, the rate of movement between screw and nut increases.

4 As the clearance increases the proportional limit and yield point decrease, but the effect is not very great for tolerances and allowances recommended by the Screw Thread Commission.

Effect of Variation in the Face Angle of the Nut:

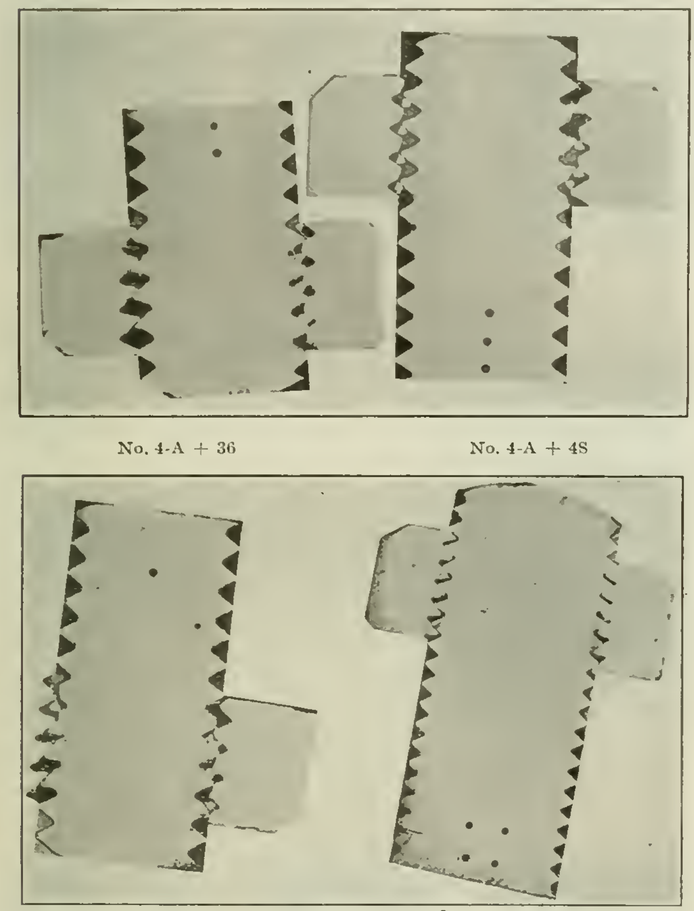
5 As the face angle of the nut with a plane perpendicular to the axis of the thread increases, the rate of axial movement of the screw in the nut increases.

6 As the face angle of the nut increases the proportional limit and yield point are practically constant for angles up to 6 deg.

Effect of Material upon the Tensile Strength:

7 Apparently the strength is increased if, instead of making the screw and nut of open-hearth cold-rolled steel, the screw is made from heat-treated nickel steel. It is possible that the increase from 7000 lb. to nearly 10,000 lb. may have been due to the use of coarse threads in the first and of fine threads in the second case.

8 For heat-treated $3^1/_2$ per cent nickel-steel screws, open-hearth cold-rolled steel nuts gave as great strength as nuts of the same material as the screws.



No. 4-A + 36 No. 4-A + 48

No. 4-A + 36 No. 5-C + 6°

Fig. 3 Sections Through Screws and Nuts after Tensile Test, Showing Failure of the Threads

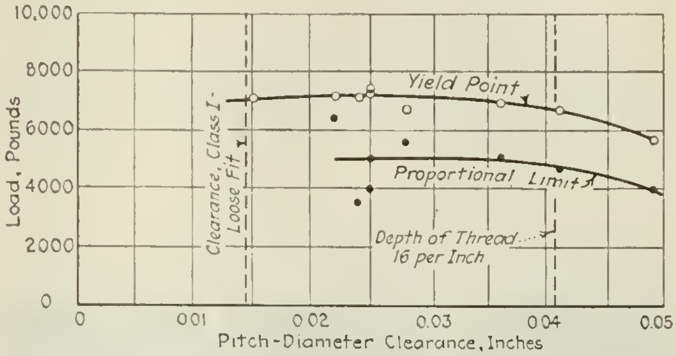


Fig. 4 Effect of Clearance on Strength of Coarse Threads, Specimens 4-A

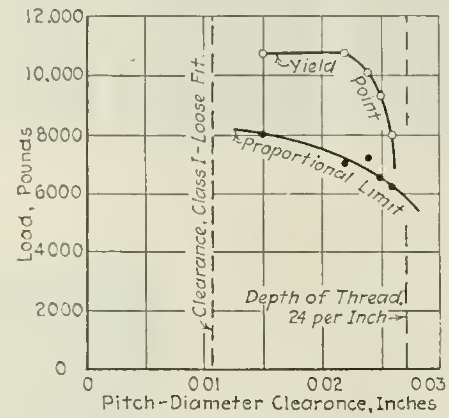


Fig. 5 Effect of Clearance on Strength of Fine Threads, Specimens 4-B

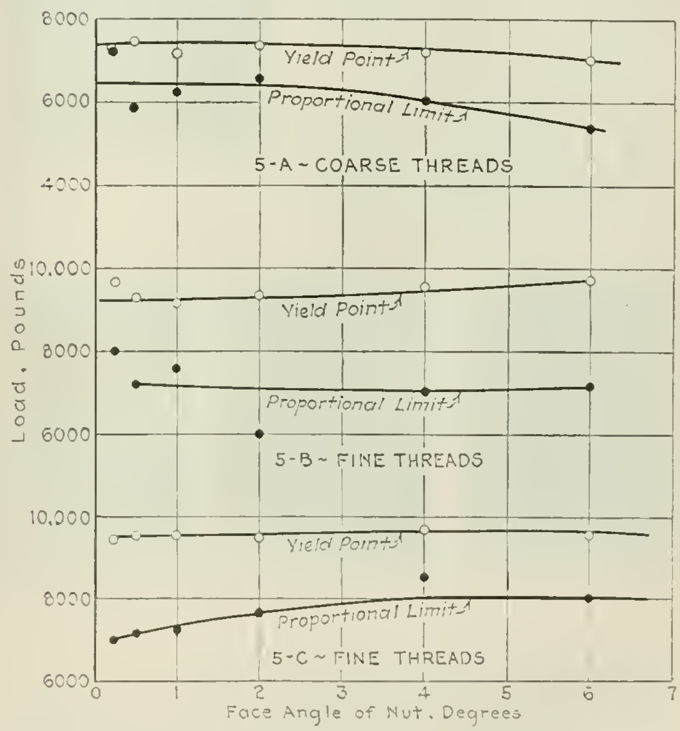


Fig. 6 Effect of Face Angle of Nut on Strength of Threads

9 The nickel-steel specimens, even when the nut was of open-hearth cold-rolled steel, showed more movement after the proportional limit was reached than the specimen having both screw and nut of open-hearth cold-rolled steel. This may prove to be an advantage if the threads are abused as by overstraining.

Chip Formation by Milling Cutters

By C. F. Roby,[1] Cincinnati, Ohio

To understand the phenomena occurring during the failure of any metal-cutting tool, it is necessary to know the mode of formation of the chip. The object of the investigation undertaken by the author and described below was to determine by observation the successive steps in the formation of a milling-machine chip. The cutting action of a turning tool has already been explained by the late Dr. F. W. Taylor and Prof. John T. Nicolson.

The machine employed for the test was a No. 3 Brown & Sharpe milling machine. By a system of indirect belt drive from an electric motor the spindle was run at the low speed of 0.2 r.p.m., giving a cutting speed of 1.5 ft. per min. A cutting speed of less than 1 ft. per min. would have been preferable, but sufficient power was not available to remove the chip at such a low speed, since the belts would slip. The ideal way to carry on an experiment of this kind would be to have the milling-machine spindle geared to the motor through the proper reduction gears, thereby making a positive drive.

Paraffin and lead were first employed as test materials, but the former crumbled under the pressure of the cutter and the latter proved to be too soft for experimental purposes. Babbitt metal, however, was found to be satisfactory, and a comparison of chips from this alloy and from steel showed that the cutting action was the same in both cases.

Tests were made with rake angles of the cutter ranging from 0 deg. to 20 deg. with the results indicated in the typical photographs reproduced in Figs. 1 to 3.

From a study of the actual formation process of the chips, and of photographs of the process, the author deduces the following conclusions:

The tool compresses the metal until the load is sufficient to shear a chip off as shown in the accompanying illustrations. After this slip has taken place, the point of the tool slides over the surface and gives it a finish. While the metal is being compressed, it is deformed and spreads out over the face of the tool. If a heavy cut is taken, this lateral strain becomes great enough to split the chip before it shears off. A small rake angle on the tool has a tendency to cause the same action. After one chip is sheared off another begins to form, and the preceding chip slips over the tool and away from the work. This slipping action is accompanied by a slight turning action, and the two combined cause the tool to wear away on the face, just back of the cutting edge. The size of the chips depends upon the kind of metal cut, the depth of cut, and the cutting speed. In the case of a soft, ductile metal such as steel, the section or chip which is sheared off does not drop away but is held in place by properties inherent in the metal, and a succession of these chips curl off and form a long shaving. Cast iron, however, acts differently, the chips dropping away directly they are sheared off.

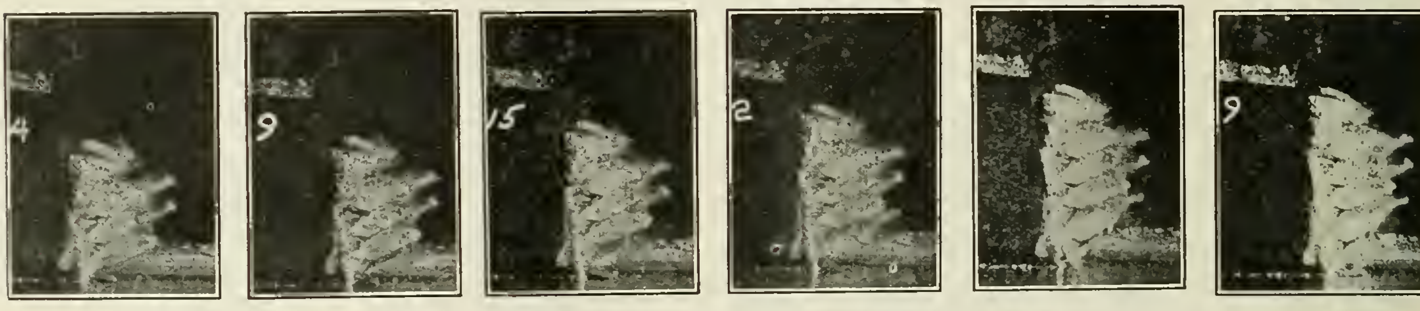


Fig. 1 Stages in the Formation of a Chip by a Tool Having a Rake Angle of 20 Deg.
(Depth of cut, 0.080 in.; angle of shear, 24 deg.)

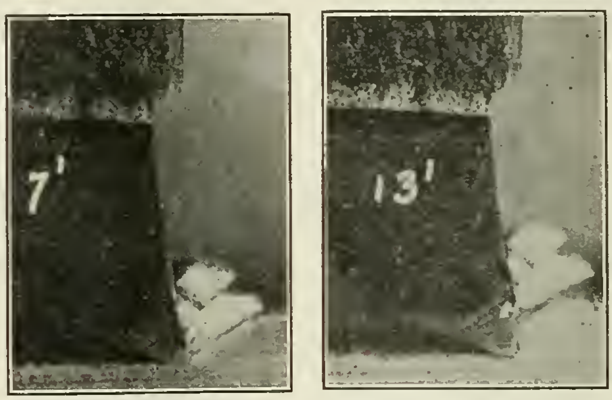


Fig. 2 Two of a Series of Fifteen Photographs of a Cut Taken by a Tool Having a Rake Angle of 20 Deg.
(Here the cut is heavier than in Fig. 1, being 0.125 in. in depth, and the angle of shear is $31^1/_2$ deg.)

Fig. 3 Stages in the Formation of a Chip by a Tool Having a Rake Angle of 0 Deg.
(Depth of cut, 0.125 in.; angle of shear, 28 deg.)

As far as the author was able to observe, there was no crack preceding the point of the tool, except at the point of shear. The angle at which shear takes place varies with the material, the depth of cut, and the rake angle of the tool. This angle increases as the cut deepens and as the rake of the tool is increased. As this angle increases the area of shear becomes less, and therefore the shearing stress becomes smaller. This may account for the fact that a thick chip is removed with less power than a thin one. This is probably true only up to the point at which the chip begins to split and crumble, after which power is wasted in deforming the chip.

Abstract of a thesis presented by the author to the faculty of the College of Engineering of the University of Cincinnati in part fulfillment of the requirements for the degree of mechanical engineer.

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The Development and Importance of Preferred-Number Series[1]

By Hilding Törnebohm, Stockholm, Sweden

All modern standardizing in the mechanical branch of industry is theoretically based upon series of numbers. The success of such standardization depends upon our ability to select an adequate series of numbers for each case, and the question of devising certain series which will fulfil the general requirements is now under consideration. The advantages to be gained from this procedure are that the numbers will be repeated; there will be a minimum number of tools of all kinds; workmen will get used to the designating numbers and will soon recognize that if another number is introduced it is to care for an extraordinary case; and those charged with the work of standardizing will in most cases know the numbers they will have to use. The construction of these series of numbers is evidently of great importance. It must not be forgotten, however, that we are hampered to a certain extent by the common practices of manufacturing, which are very often far from the ideal. A study of such series of preferred numbers and how they may be constructed will be the object of the following discussion.

The simplest of all series is the normal succession 1, 2, 3, 4, 5, 6, 7, 8, 9, and so on. If this series were always employed, all decimals would disappear. We have also to consider other than metric series, for instance, one for screw diameters, specified in inches, which will give figures ending in decimals if they are converted into millimeters. Since the above-mentioned series has very small intervals, at least for the practical manufacturing of articles of large size, it is not an ideal one for standardizing purposes. The desired economies would not result if the manufacturing were done according to a series whose intervals were smaller than necessary.

It is generally the case in standardizing that a fixed amount cannot be taken as the difference between the successive sizes in a series of articles of the same kind. The difference must be specified in percentage of the size, which indicates that a series used for standardizing purposes ought to be geometrical instead of arithmetical.

It may be asked if the geometrical series can be recommended in all cases, or if not, how the series used in standardization should be built up.

If the different numbers in a series are laid out along a line, as OX, Fig. 1, the numbers will be represented by the lengths L_1, L_2, L_3, etc. Suppose that for a certain size it is desired to use a dimension represented by the length L. This dimension, which may have been obtained by calculation according to the strength of the material, lies between L_n and L_{n+1}. If now it is desired to use a standard size, it will be necessary to employ either L_n or L_{n+1}. If the dimension L was very closely calculated, it is possible that the dimension L_n cannot be allowed, in which case L_{n+1}, will have to be used, or one larger than needed. This will result in a loss if the larger size, being a standard one, is not just as cheap or cheaper than the L, which would have to be manufactured specially.

If the article with the dimension L could be manufactured in the same way as if the dimension were L_{n+1}, it would certainly mean a loss were we to use the latter. This loss would, to a certain extent, be represented by the distance $L_{n+1} - L$ and the maximum value it could reach would be $L_{n+1} - L_n$, which would be when $L = L_n$.

If the cost of a certain detail of a standard size with its principal dimension $= L_{n+1}$ be denoted by $f_m(L_{n+1})$, and the cost of the same kind of an article of a special size with its principal dimension $= L$ by $f_s(L)$, and if it be assumed that the difference between the principal dimensions of two articles of standard size will have to be of such an amount that it will not pay to manufacture a special size in between two standard sizes, the following limiting equation can be written:

$$f_m(L_{n+1}) = f_s(L_n)$$

This equation gives the largest amount of the difference between the principal dimensions of two articles of standard size that is consistent with economical production.

For convenience make the principal dimension L_{n+1} equal to $L_n + a_n$. The interval at L_n is then represented by a_n and the equation will be

$$f_m(L_n + a_n) = f_s(L_n)$$

Without serious error it can be assumed that

$$f_s(L) = k\,f_m(L)$$

which implies that the cost relation between a standard article

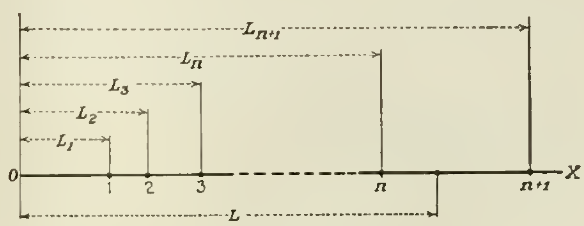

Fig. 1

of a given size and a special article of the same size is constant for all values of L. Whence

$$f_m(L_n + a_n) = k\,f_m(L_n) \ldots\ldots\ldots\ldots\ldots [1]$$

The constant k can evidently be modified so that the equation will serve for general conditions as well as for maximum. It will then hold good for all standard values of L.

It would be possible to make up a standard series, by substituting suitable constants in Equation [1], and then solving for a in terms of L. Such a procedure would of course be somewhat laborious, but the intention is not to use the equation in practice but to derive certain general rules by studying one or two special cases.

Assume that the costs for a series of a given kind of article are in proportion to the main dimensions. This supposition is valid, especially when all dimensions of the articles except the principal ones are constant, these latter being variable. For example, if $^3/_8$-in. screws of a certain kind are to be standardized with regard to their lengths, the principal dimension in this case will be the length L, and we can write

$$f(L) = AL + B$$

Equation [1] will then read

$$A(L + a) + B = kAL + kB$$

or

$$a = (k-1)L + \frac{B}{A}(k-1) \ldots\ldots\ldots\ldots\ldots [2]$$

Equation [2] is that of a straight line.

If in Fig. 2 the first dimension is L_1, L_2 and L_3 are obtained in the way there indicated.

Taking another example, let it be assumed that the cost varies along the curve of an equation of the second degree. Then

$$f(L) = AL^2 + BL + C \ldots\ldots\ldots\ldots\ldots [3]$$

[1] The principles set forth in this comprehensive discussion of the subject of preferred numbers are accepted by the Sveriges Maskinindustriförenings Standardkommission (Standards Commission of the Swedish Machine Trade Association), of which the author, a civil engineer, is a member and Mr. Erik Fornander the secretary. The A.E.S.C., which received this discussion and has transmitted it to Mechanical Engineering for publication, points out that it is the first one to give quantitative consideration to the economies obtainable through the adoption of preferred-number series.

If this value of $f(L)$ is inserted in Equation [2], it will be found that the value of a often varies along the branch of a hyperbola, as is shown by the dotted line in Fig. 2.

Assuming that the function varies along the curve of an equation of the third or fourth degree, values will be obtained which follow the above-mentioned branch of a hyperbola very closely. The branch of a hyperbola approaches a straight line, which indicates that the intervals ought to form a geometrical progression.

In constructing series of a geometrical nature, mixed numbers often result. Naturally when arranging a standard series it is desirable to use only whole numbers, and one way of doing this is to round off the mixed numbers to the nearest whole numbers. For the purpose of developing a law for selecting numbers and in

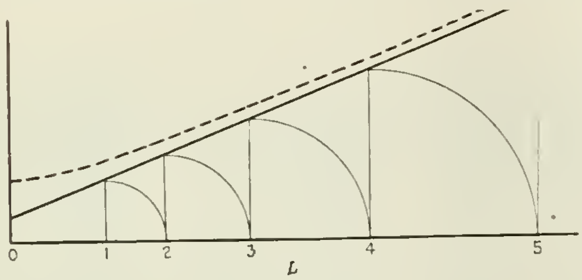

Fig. 2

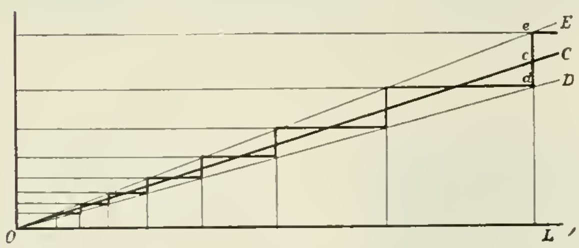

Fig. 3

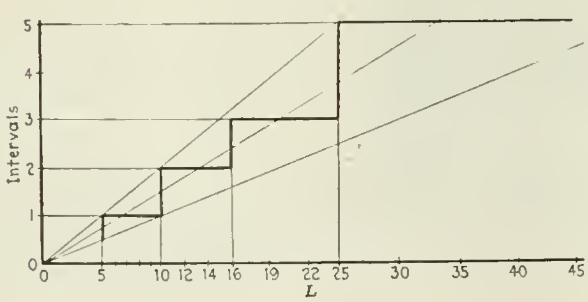

Fig. 4

addition providing for the introduction of specially preferred numbers into the series, the following method can be recommended.

In Fig. 3 the straight line OC represents the costs. This line passes through the origin O, as obviously the cost of an article of zero dimension must be nothing. On both sides of the line OC other straight lines OD and OE are so drawn that they intersect any ordinate at equal distances above and below the line OC, that is, $dc = ce$. These two lines can very well serve as limits for the departure from the straight line OC. It is seen then that the departure at any value of L will be a constant percentage of L.

The Swedish Standards Commission has, in selecting a series of numbers for lengths, proceeded in the above-mentioned manner. The result is the following series: 5, 6, 7, 8, 9, 10, 12, 14, 16, 19, 22, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 120, 140, 160, 180, 200 . . . etc. (see Fig. 4). It may not appear rational, when we are uncertain as to the constants which have to be used, to devise a series in this way, but we must bear in mind that systematization is necessary in all standardization, otherwise we would have to expect changes as a consequence in the future. Changes, however, may become necessary for any number of reasons. This series has been tried out for a number of years in Swedish works with good results, but of course it may eventually become necessary to introduce a few additional numbers.

The German Standards Commission has without hesitation adopted the idea that series for standardizing purposes ought to be geometrical. The German solution of this problem, which must be considered a very good one, especially in the case of type standardization, is simply that $\sqrt[10]{10}$ is taken as the ratio in the geometrical progression. The reason why this ratio is selected is that the tenth term will be ten times as large as the first term. The series is as follows:

1	10	100
1.2	12.5	125
1.6	16	160
2	20	200
2.5	25	250
3	30	300
4	40	400
5	50	500
6	64	640
8	80	800
10	100	1000

In addition to the foregoing series, Germany has introduced others[1] having the ratios $\sqrt[5]{10}$, $\sqrt[20]{10}$, and $\sqrt[40]{10}$. As the extremes in all these series are either 1 and 10 or 10 and 100, some of the mean terms will be alike.

In the standard sheet DINORM 323 Bl. 1, issued by the Normenausschuss der Deutschen Industrie, it is specified that the series with the ratio $\sqrt[5]{10}$ (1, 1.6, 2.5, 4, 6, 10, 16, 25, etc.) shall be used wherever it is possible. When not, the next series, ratio $\sqrt[10]{10}$ (1, 1.2, 1.6, 2, 2.5, 3, 4, 5, 6, 8, 10, etc.) is to be considered. If a series with still smaller intervals is desired, the series with the ratio $\sqrt[20]{10}$ may be used. The last series, with the ratio $\sqrt[40]{10}$, has such small intervals that its first term is 10, and it will naturally be used only in extreme cases. It is further stated on the standard sheet that these four series are to be used in the standardization of different sizes of machines of the same type, apparatus, buildings, etc., but for normal finished diameters another is recommended.

In the opinion of the author, the German series have but one defect, which is that the number 12.5 has been considered necessary in the $\sqrt[10]{10}$ series; however, a rounding off of this number to 12 would bring about uneven steps in the $\sqrt[40]{10}$ series.

It has been stated that different purposes call for different series, such as series for standardization of types, of normal diameters, and of lengths. What, it may be asked, is the difference between these series, and why should not one series be sufficient? From the author's point of view it is quite necessary to distinguish between the various series used for standardization on account of the entirely different character of the subjects standardized.

A single example will show that geometrical series alone are not enough for standardizing purposes. The values of our coins form a standard series which is not and could not be geometrical. The stipulation for the coin series is that the sum of two or more coins must equal the value of a larger coin. This result cannot be obtained by a geometrical series.

The following classification of the various series required in standardization work will be of interest.

1 *Series for Types.* These series have to be used for standardizing principal dimensions such, for example, as diameters of threads, diameters of pulleys, internal diameters of ball bearings, machine tools, candlepower of incandescent lamps, output of motors, etc. The German series are applicable for this group of standards but cannot cover all cases, some exceptions being diameters of threads, diameters of pipes, etc.

2 *Series for Lengths.* These series are suitable for standardizing different sizes within each type; for example, lengths of screws, lengths of threads, widths of pulleys, etc.

3 *Series for Normal Diameters.* These series are usable for standardizing gages for diameters. A series of normal diameters is intended for the purpose of reducing the number of such tools.

(*Continued on page 613*)

[1] The numbers of these series are given in Table 4 of the paper on Size Standardization by Preferred Numbers, by C. F. Hirshfeld and C. H. Berry, in Mechanical Engineering, December, 1922, p. 791.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

Nusselt's Coefficients of Heat Transmission and Their Range of Application

By ALFRED SCHACK

The author discusses the coefficients of heat transmission previously determined by Nusselt, the mean temperature of a cross-section, and the mean true temperature of a stream of liquid or a gas. He criticizes the precision of Nusselt's experiments and offers practical methods for measuring quantities of heat.

If t_R is the temperature of the inner wall of a pipe, t_G the temperature of the fluid (gas or liquid) flowing through the pipe, then the amount of heat transmitted per hour per square meter of surface from the pipe to the gas or vice versa is

$$Q = \alpha \times (t_R - t_G) \text{ (cal. per sq. m. per hour)} \quad \ldots\ldots [1]$$

where α is the coefficient of heat transmission.

Contrary to views formerly held, it has been found that this coefficient is not only not constant but is highly complicated and has been until now an imperfectly known function of the properties of the fluid, pipe, velocity of flow, etc. W. Nusselt in 1909 was the first to throw a clear light on the nature of this coefficient.

The author claims, however, that both Nusselt and his successors have failed to take into consideration certain factors affecting the precision of measurement of temperature. The temperature is not at all uniformly equal through the cross-section of the pipe and neither are the components of velocity in a turbulent flow lying in the direction of the flow. When the temperature of the gas is lower than that of the pipe the layers of gas lying nearest the wall of the pipe are hottest, and yet the velocity of flow of the gas there is zero.

On the other hand, it is obvious that the amount of heat carried off per hour by the gas through any part of the cross-section of the pipe is proportional to the velocity and temperature of the particles flowing through the given cross-section. If, therefore, it be assumed that contrariwise to the conditions in the Nusselt test the gas is hot while the pipe is cold, the amount of heat flowing through the cross-section will be obviously different from that which will flow in the case where the pipe is hotter than the gas, and will be different notwithstanding the fact that in both cases the mean temperature of the cross-section, the velocity of flow, and all the other conditions are equal. The velocity distribution may be equal in both cases, the temperature distribution is not. When the pipe is hot the temperature of the gas reaches its maximum near the pipe wall and its minimum in the interior, while the contrary prevails when the gas is hot and the pipe is cold.

If the products of velocity and temperature in the various parts of a cross-section are obtained and added up, it will be found that the flow that carries the greatest amount of heat through a given cross-section is one in which the maximum temperature is in the inside of the pipe, since in that case the maximum of temperature coincides in locality with the maximum of velocity of flow. With the same mean value of temperature through a cross-section, the same velocity of flow, the same dimensions of pipe and the same gas, the amount of heat carried through a given cross-section per hour will be greater in the case of a pipe that is colder than the gas than in the case of one that is hotter.

The most significant thing in both cases is, however, that in neither of the two will the "true heat" carried through a given cross-section be found by a process of multiplying the correctly determined mean temperature of a cross-section by the correct velocity of flow and the correct specific heat of the gas. In the first case excessively large, and in the second case excessively small, heat values will be found. It therefore becomes necessary to introduce a new kind of average temperature of gas which the author calls the "true mean temperature," which, when multiplied by the velocity and specific heat of the gas, will give the amount of heat actually flowing through a pipe cross-section, irrespective of whether the pipe wall is colder or warmer than the fluid passing through the pipe.

It was Gröber who first called attention to the existence of a difference between the mean temperature t_Q of a cross-section and the true mean temperature t_G of a gas stream. He found that the Nusselt values deviate from the true values by as much as 40 per cent. Gröber claimed that the Nusselt coefficient of heat transfer was improperly expressed. Actually, however, it is not the definition of heat transfer, which is purely arbitrary, but the method of measurement used by Nusselt that is answerable for the incorrect results.

The present author claims that it can be shown that even with the constant α which Nusselt used, his results would have been quite close to the true values if only he had used a pipe that was colder than the gas, and had thus worked with the direction of heat transfer opposite to that which he actually had in his tests. By employing as a foundation the theories of Prandtl and Von Karman an expression may be derived for the difference between the "true mean" gas temperature and the mean temperature of a cross-section, namely,

$$t_G - t_Q = \frac{1}{72}(t_A - t_R) \quad \ldots\ldots\ldots\ldots\ldots\ldots [2]$$

where t_A is the temperature of the gas at the axis of the pipe and t_R the temperature of the pipe wall, both in degrees centigrade. From this expression it would appear that, contrary to the opinion of Gröber, the values in the individual tests of Nusselt are at most 6 per cent too high, and in the majority of instances considerably less in excess of the true values. The case would have been the same had Nusselt in his measurements actually determined t_Q instead of t_G. He did not do this, however, and an entirely new situation is thus created. For his measurement of temperatures Nusselt used a spirally wound resistance thermometer which did not touch the pipe wall. It may be shown that on account of this a temperature was measured which is materially nearer the true mean temperature t_G than the mean temperature of cross-section t_Q. Furthermore, since Nusselt did not find any appreciable effect of the influence of the pipe length, i.e., the distance between the two points of measurement, it may be concluded that the temperature which he measured lay quite close to t_G. It may further be shown that the radiation from the hot pipe walls could have caused an error which even under the most favorable conditions did not exceed 1 per cent. Taking everything into consideration, it would be fair to estimate the possible error in the Nusselt formula as being at most under 2 per cent, though it cannot be stated whether the deviation is positive or negative.

It would appear that in experimental measurements such as those of Nusselt the difference between t_G and t_Q is not of great importance. The situation is different at times, in particular in heat measurements on flowing gases and liquids, which are of great importance in metallurgical industries. Here one also has to deal with the true temperature t_G, and the question arises as to what is the correct method of measurement by simple means. If a thermometer properly protected against radiation be placed in the axis

of the pipe, i.e., the place where the highest temperature prevails, a temperature about 12.5 per cent higher than t_G will be obtained ($t_R = 0$). Calculation would indicate that the true gas temperature is a resultant of the temperature at the axis of the tube t_A and the temperature of the wall of the pipe t_R in accordance with the expression

$$t_G = \frac{8}{9}t_A + \frac{1}{9}t_R \qquad [3]$$

This is under the assumption that there is a completely evolved state of velocities and temperatures, and that the measurements are taken at a point several diameters back of the last interruption of a smooth straight pipe. According to Equation [3], t_G may be determined from two measurements, t_A and t_R. It is possible to determine t_G by a single measurement in the following manner. If the cross-section of the temperature field of an undisturbed turbulent flow be plotted and on it be plotted the computed mean true gas temperature t_G, the intersection of the straight line t_G with the temperature curve will be found at a distance $^1/_8$ of a diameter from the wall of the pipe whether the pipe be cooler or warmer than the gas, the diameter here being the inside diameter of the pipe. As it is rather difficult to maintain a distance of $^1/_8$ of a diameter from the pipe wall, it is advisable to err in the direction toward the center of the pipe rather than toward the wall, since in the first case the error is comparatively small while in the latter it is large. In order to determine the true gas temperature in an undisturbed turbulent flow of gas or a liquid, the bulb of the thermometer or the contact point of a thermoelement should be held in the stream at a distance from the wall of the pipe equal to $^1/_8$ of its internal diameter. (In actual practice, however, it is difficult to obtain in the case of pipes of large diameter undisturbed flow of the fluid.)

From this the author proceeds to an investigation of the extent of the field in which the Nusselt formula holds good. In this connection he considers the question whether the Nusselt formula is applicable to such conditions as occur, for example, in metallurgical plants, and comes to the conclusion that it is not. This is due to the fact that the formula is based on the assumption that the drop of temperature at the tube wall in the radial direction is proportional to the product of powers of all the magnitudes on which it is dependent. In order, however, to be able to apply the principle of similarity, it must be further assumed that all the exponents of these variable quantities are constant, and this cannot be done except on experimental proof. Nusselt's own tests have shown that this is so, but only within the range of his experimental work. There is no question but that within a limited range any function may be very closely represented by a power of a variable, but a conclusion should not be drawn from this that further variations of the function may likewise be expressed by the same power. In other words, it should not be assumed that one may safely extrapolate to any degree whatsoever, or that in this expression the true organic law of the function has been found. However, the chances are that in the majority of cases within some different range of the application of the function another exponent will have to be selected for the variable in order to express the functional variation, and the ranges covered by each of these exponents may be of variable extent.

It follows from this general expression that it is quite unlikely that all the exponents expressing the radial drop of temperature at the tube wall in accordance with the Nusselt formula would remain constant even after a material change in the experimental conditions, particularly as the Nusselt formula does not represent the true function with respect to α. It is merely a mechanical approximate formula not capable of extrapolation, intended to express the still unknown physical law. Because of this the availability of the Nusselt formula in no way eliminates the necessity of tests in fields of application where conditions differ materially from those which obtained during Nusselt's own tests. On the other hand, extrapolation is permissible in cases where conditions do not materially differ from those in the Nusselt tests, for example, with smooth pipes up to 10 cm. (4 in.) inside diameter. It should not be applied, however, to the cases of brick-lined passages, etc.

In particular the influence of radiation makes it inadvisable to apply without further reservations the Nusselt formula under certain conditions to the case of hot gases containing water vapor or carbon dioxide. Contrary to what happens with air, carbon dioxide and water vapor and possibly the majority of other triatomic and polyatomic gases are not entirely transparent to dark radiations. Their absorption (the original article gives some figures) depends on the wave length and is roughly of the order of 50 per cent of the total radiated energy. (Abstract of a more extensive investigation by the author in preparation for publication. Abstracted through *Stahl und Eisen*, vol. 43, no. 29, July 19, 1923, pp. 942–946, *tA*)

Short Abstracts of the Month

AERONAUTICS (See Internal-Combustion Engineering)

ENGINEERING MATERIALS (See also Railroad Engineering)

Some Compressive Tests of Hollow-Tile Walls, Herbert L. Whittemore (Mem. A.S.M.E.) and Bernard D. Hathcock. The Bureau of Standards has published the results of tests of hollow building tile in its Technologic Paper No. 120. The work was done in coöperation with committee C-10 on hollow building tile of the American Society for Testing Materials. As the strength is important when built into a wall, similar tile were used in constructing 32 walls each 4 ft. long, 12 ft. high, and either 6, 8, or 12 in. thick. The National Fire Proofing Company donated all the tile, which were of such design that all the net area was in bearing when carefully set on end in the wall. As the strength of these tile was greater than the strength of the average tile used in buildings, the results of this investigation should be used with discrimination.

The mortar used was a mixture of the following proportions: 1 cu. ft. of portland cement, $^1/_4$ cu. ft. of hydrated lime, and 3 cu. ft. of sand dried in an oven. The walls were laid with great care by an experienced mason, and were of much better workmanship than is usually obtained.

The walls were, with a few exceptions, tested when one month old. After placing a wall in the testing machine, it was capped with plaster of paris, the upper head brought into contact with the wall, and the cap allowed to set for 12 hr. or more.

Compressometers were placed at each corner, and readings taken during the test. Stress curves were drawn to show the behavior of the walls. Strain-gage readings were also taken, both on the tile and across the horizontal joints. Due to the great differences in the modulus of elasticity of the tile and the lack of data on the modulus for the particular tile on which strain-gage readings were taken, these readings were of little use. The horizontal deflections of the walls were measured at midheight of the walls.

The following conclusions may be drawn from the results of the tests:

a Although the strength of the individual tile in lot A was about twice that for the tile in lot B, the strengths of the walls made from these tile were only slightly greater.

The ultimate strength of the walls made from the A tile averaged about 37 per cent of the strength of the individual tile, while those made from the B tile averaged about 55 per cent.

b From the theory of columns, it might be expected that a thick wall, the height being the same, would sustain a greater load than a thin one. These tests, on the contrary, show no effects that can be definitely ascribed to "column action." This is confirmed by the small deflection of the walls.

c Apparently there is no relation between the ultimate strength of a wall and the load at the first crack.

d The walls having the cells of the tile vertical had, on the average, more than twice the strength of those having the cells horizontal. For both these cases the values of the stress at failure were remark-

ably constant, being apparently independent of the size of the tile. The ultimate stresses computed on the net sectional area were also somewhat greater for the walls having the cells vertical, except for the 6-in. A tile, for which the stresses in the walls having the cells horizontal were slightly greater. Apparently the advantage of setting the tile with the cells vertical is greater for eccentrically loaded walls than for walls which are axially loaded.

e In only one case could a direct comparison be made between "broken" and "unbroken" joints. Wall No. 31 with "broken" joints, but in all other respects identical in construction with walls Nos. 25 and 26, which had "unbroken" joints, shows a much higher strength. Conclusions, however, should not be drawn from the results from one specimen. Attention is called to the fact that in these tile the transverse webs were spaced to give full bearing over the end of the tile when the cells were vertical and the joints "broken," as well as when the joints were "unbroken."

f For the axially loaded walls, the failure was sometimes by crushing at the top and sometimes by vertical cracking through the joints. No consistent difference in strength was found for these two types of failure. Probably the crushing at the top was determined by the plaster cap, which was somewhat weaker than the mortar joint.

g Walls loaded with an eccentricity of 2 in. over one-half the width of the wall had about one-half the strength of similar walls axially loaded. Apparently this ratio is independent of the thickness of the wall. The maximum deflection for the eccentrically loaded walls was, on the average, 0.04 in., undoubtedly a very small value, which was exceeded by six of the axially loaded walls.

h Failure, in the case of the eccentrically loaded walls was local. The upper bearing plate rested on two of the webs of each tile in the upper course. The stress in these webs was therefore much greater than in the lower courses in which the load was more uniformly distributed.

i The modulus of elasticity of the walls varied over a wide range, and apparently there is no relation between the modulus for the wall and that for the individual tile.

j Due to the wide variations in the moduli of elasticity of the tile and in the deformation of the joints, it seems probable that failure of a tile wall is caused by the unequal distribution of the stresses. Therefore any means of securing a more uniform stress distribution, such as selection of tile having the same physical properties and setting them with a uniform thickness of joint, would be expected to increase the strength. (Abstract of *Technologic Paper of the Bureau of Standards*, no. 238, *e*)

Invar and Related Nickel Steels. This circular of the Bureau of Standards is mainly a compilation of data obtained during the last 30 years by various investigators of the different properties of nickel steels. Particular attention is given to "invar," a nickel-iron alloy containing about 36 per cent nickel and possessing an extremely small thermal expansivity at ordinary temperatures, the mean coefficient of linear expansion between 0 and 40 deg. cent. being on the order of 1 to 2 millionths. The results of investigations made on the various properties of the nickel-iron alloy series are presented largely in diagrammatic and tabular form.

The anomalous behavior in the thermal expansion of nickel-iron alloys at various temperatures is illustrated by a number of diagrams. The degree of thermal expansivity reaches a minimum in alloys with about 36 per cent nickel (and 0.4 per cent manganese and 0.1 per cent carbon), and the position of this minimum may be modified by the presence of added elements as chromium, etc., and also by thermal or mechanical treatment.

The thermal conductivity and specific heat of nickel-iron alloys show minimum and maximum values, respectively, at about 35 per cent nickel.

Some data on the mechanical properties and also Brinell and Shore scleroscope hardness numbers of nickel steels with the nickel content ranging up to about 50 per cent are given in both tabular and diagrammatic form. The tensile properties of invar may run as follows: Tensile strength, 50,000–100,000 lb. per sq. in.; elastic limit, 30,000–70,000 lb. per sq. in.; elongation, 25 to 50 per cent; and reduction of area, 40 to 70 per cent.

Nickel steels present anomalies in the elastic modulus corresponding closely to those found in thermal expansion. It has been found that the degree of anomaly can be reduced in very large measure by means of suitable additions made to the alloy, namely, about 12 per cent chromium or its equivalent, this alloy having recently been introduced under the trademark "elinvar." This is of practical importance in the construction of watches and chronometers, where the degree of error with variations of temperature and consequent need for compensation may be made very small.

Resistance to corrosion by fresh and sea water and acid liquors increases with the proportion of nickel. An alloy containing about 18 per cent may be regarded as practically non-corrodible. The resistance of invar to oxidation, while very much greater than that of ordinary steel, is not perfect, therefore it is advisable to coat an invar instrument with a protective coating such as vaseline if it is to be exposed for a long time in a moist atmosphere.

The extent and nature of applications of nickel steels are discussed. A list of makers of nickel steels and dealers in nickel steels of minimum thermal expansivity in America and also a selected bibliography are included. (*Abstract of Circular of the Bureau of Standards*, no. 58, 2nd edition, *de*)

FOUNDRY

Pressure System of Pouring in a Non-Ferrous Foundry, Roy E. Paine. Data on a process for making castings without risers or feeding heads, developed in a brass foundry in San Francisco:

In this case the metal is poured through a square gate at the bottom, and usually a small horned gate is used. This is connected to a vertical gate about twice the diameter of the bottom gate and extending 18 in. above the top of the casting. Of course greensand molds must be rammed firmly to withstand the pressure exerted by the metal while in a fluid condition and to prevent the metal from straining or from burning on to the face of the mold. The problem of cores is particularly difficult in connection with the system of pressure casting, but a core mixture has been developed which makes a core that does not burn on and that is removed easily. Temperature of the metal exerts a great influence on the successful application of pressure casting.

It is claimed that the pressure system of pouring castings offers several advantages. It is not necessary to make provision for risers, feeding heads, and heavy gates. Castings do not have to be burned where shrinkage has left large holes at the gate of feeding head. It is also claimed that a denser casting is secured and that costs of cleaning are reduced. (*The Foundry*, vol. 51, no. 14, July 15, 1923, pp. 559–561 and 597, 10 figs., *d*)

Die Castings for Owen Sound Plant, Herbert Chase. Data of the practice in the plant of the Stewart Manufacturing Corporation building die-casting machinery for the Aluminum Products Manufacturing Co., Owen Sound, Ont., and also in the plant of the latter company.

Three general types of die-casting machines are employed: a horizontal type used chiefly for the smaller castings made in other than aluminum-base alloys, a vertical type used for larger castings of the same character, and an aluminum machine used entirely for aluminum-base castings. The three types operate on the same general principle, but are quite different in appearance. All types have the following essential parts: two members for carrying the two halves of the die, so arranged that the dies can be held closed under considerable pressure during the casting operation and then quickly opened to eject the casting; two core carriers, usually arranged to move at right angles to the direction of motion of the dies; and a metal pot arranged to be moved up to the die, or the die up to it. Each type has somewhat differently arranged means for controlling the motion of the various parts.

The operation of these types is described in some detail. The machine for casting aluminum alloys is different in appearance from the other machines but is substantially identical in principle. The halves of the die are pneumatically operated in this case, but instead of moving the metal pot up to a stationary die, the entire head of the machine containing both the die and its operating mechanism is moved up to a stationary metal pot. The metal pot is

closed and sealed to reduce oxidation and contains the molten aluminum at a temperature of about 1500 deg. fahr.

In connection with the design of parts to be die cast the following points should be borne in mind:

1 Avoid undercuts on inside surfaces so far as possible.

2 Allow, in the case of aluminum, for a draft of 0.005 in. per in. of length and of diameter of cores. On white-brass cores allow a draft of 0.002 to 0.003 in. per in.

3 Uniformity of section tends to prevent cracking. When thick and thin sections are necessary, the transition from one to the other should be as gradual as possible.

4 Allow fillets whenever possible. Even a very slight fillet is better than none at all.

5 The minimum thickness of section practicable varies considerably with the area of the section. One-sixteenth of an inch is usually the practical minimum in the case of aluminum and $^1/_{32}$ in. in white brass, but thinner sections have been cast in some cases.

6 The minimum size of hole which it is practicable to cast in aluminum is about $^1/_{16}$ in. when the hole is not more than $^1/_4$ in. deep, or $^3/_{32}$ in. for a hole $^1/_2$ in. deep. In the case of white brass a $^1/_{16}$-in. hole is practicable if the length does not exceed $^1/_2$ in., while a $^3/_{32}$-in. hole of almost any length can be cast readily.

7 The use of knife edges should be avoided.

(*Canadian Foundryman*, vol. 14, no. 7, July, 1923, pp. 20–22 and 27, 3 figs., *dp*)

FUELS AND FIRING (See also Power-Plant Engineering, Testing and Measurements)

Surface Combustion and Radiophragm Heating, Prof. Wm. A. Bone. This paper opens with a brief historical account of the development of surface combustion, including the work of the author and that of the late C. D. McCourt.

One of the recent developments in this direction is that of the radiophragm. This is based on a process developed by the author and his collaborator McCourt in 1909, in which a homogeneous mixture of gas and air in the right proportions for complete combustion was made to flow from a suitable feeding chamber at the back to a porous diaphragm of refractory material and caused to burn without flame at the surface of exit, which was thereby maintained in a state of red-hot incandescence. The recent improvements lie in the new methods of manufacturing the radiophragm itself.

The actual method of making these radiophragms, however, is not described and only general statements as to tests are made concerning them. It is said that they are used for cooking and that there have also been constructed and are at present on trial appliances for lead melting, type founding, hardening and tempering of metals, and other purposes.

An extensive reference is also made to surface-combustion boilers, but no new data in this connection are presented. (*Jour. Royal Society of Arts*, vol. 71, no. 3686, July 13, 1923, pp. 596–601 and discussion 601–611, 6 figs., *dg*)

Comparative Tests of By-Product Coke and Other Fuels for House-Heating Boilers, Henry Kreisinger, John Blizard, H. W. Jarrett (Members A.S.M.E.), and J. J. McKitterick. One of a series of reports published by the Bureau of Mines for the purpose of disseminating information regarding the fuels best adapted for heating houses. It gives the result of tests that were made to compare by-product coke, bituminous coal, and anthracite as fuels for small boilers.

A brief summary of the results is given in a table which shows that the efficiency was as high with by-product coke as with anthracite. In fact, the two Capitol boilers gave somewhat higher efficiencies with coke than with anthracite. The efficiencies obtained with Pittsburgh and Illinois coal were 8 to 20 per cent lower than that obtained with by-product coke.

The Pittsburgh tests showed that about 10 tons of Pittsburgh coal was equal to 9 tons of coke or $8^1/_2$ tons of anthracite when the fuels were burned in the Arco boiler; and to 10 tons of coke or 9 tons of anthracite when burned in a Dunning boiler.

The Minneapolis tests showed that about 10 tons of Illinois coal was equal to $7^1/_2$ tons of coke or anthracite when burned in the small Capitol Winchester boiler, and equal to $8^1/_2$ tons of coke or anthracite when burned in the larger Capitol boiler.

With the same attention to the fire, coke gives a much more uniform temperature than bituminous coal. In addition, coke is a clean fuel and makes neither smoke nor soot, an advantage difficult to express in exact figures. It is nearly as good a fuel as the domestic sizes of anthracite, and if anthracite is unavailable at reasonable prices a by-product coke makes a good substitute. (*Technical Paper no. 315 of the U. S. Bureau of Mines*, May, 1923, 21 pp., 8 figs., *p*)

Explosive Tendencies of Pulverized Coal, Hartland Seymour. The author calls attention to the hazards which arise in connection with the utilization of pulverized coal, stating at the same time that little danger is involved provided reasonable care is taken to comply with well-established precautions.

Powdered coal in bulk is not especially explosive, but when raised in a cloud it is as dangerous as a nozzle discharging gas into the open air. One form of coal dust which is exceedingly dangerous and to which perhaps too little attention is paid is that coming from small heating furnaces in which pulverized coal is used as a fuel. These furnaces are comparatively small and are used principally to heat bars and rods for forgings.

The pulverized coal is shot under pressure, and some of it is apt to get out into the surrounding atmosphere as flowing dust and finally settle all around the place.

A rather peculiar accident happened some time ago from dust of this kind in one of the Pittsburgh steel mills. At one point in the building an electric switch was so situated that dust could settle between the poles. One Sunday, when the mill was shut down, sufficient dust accumulated to form a short-circuit, and as a result a whole panel of the switchboard in the power house was burned out. Many accidents have occurred practically all of which were due to the dusty and unclean condition of the buildings. Some risks, however, are more or less connected with the apparatus used in pulverizing the coal and delivering it to the point of consumption; and though it is true that reduction of the fire and explosion risks rests largely with those operating such plants, yet much can be done through proper inspection by well-informed authorities having proper jurisdiction. In order to get an adequate understanding of these risks and their remedies a working knowledge of the methods and machinery used in pulverized-fuel plants is necessary. A brief description of these methods and equipment therefore may be of value.

From these the author proceeds to discuss the chances of explosion in a driers elevating and conveying plant, storage bins, etc. The article is based practically exclusively on American data taken from the Bureau of Mines and the American Railway Association. (*The Chemical Age*, vol. 9, no. 215, July 28, 1923, pp. 82–84, *d*)

FURNACES

Air Circulation in Dry Kilns

Air Circulation in Dry Kilns. Circulation of the air in a dry kiln is a very important factor in the artificial seasoning of wood. Without a controlled movement of the air it is impossible to maintain the proper temperature and humidity uniform throughout a kiln. Evaporation of moisture from the wood cools and humidifies the atmosphere next to the wood. In order that drying may progress it is continually necessary to replace this cooled, moistened air with a fresh supply of warmer, drier air. This can be accomplished only by a good circulation which will remove the moist, cool air from the kiln or will return it to the lumber after it has been warmed and dried.

In any kiln a certain amount of circulation is natural. The heating coils are continually heating the air, and the evaporation of moisture from the wood and heat losses through the building walls are continually cooling the air. The heated air rises. Some of it escapes through cracks at the top of the kiln, and the rest of it enters the lumber where it is cooled as it picks up moisture. The cooled air drops and is recirculated over the heating coils until it is warm enough to rise again.

If flues or vents for the escape of hot air from the kiln and intakes

for the entrance of cold air are provided, the natural circulation can be considerably increased. The kiln, being warmer than the surrounding atmosphere, will act as a chimney, and the draft that is created will speed up the movement of the air inside the kiln. Circulation may be further increased by the use of inspirators, aspirators, or steam-spray lines. A steam jet in the intake duct is a good inspirator. Aspirators may be in the form of a coil of steam pipe in the uptake flue. Steam-spray lines running the full length of the kiln may be installed in the passages through which the air returns from the lumber to the heating coils if the design of the kiln permits. These steam-jet lines act as recirculators and humidifiers. Their successful operation depends upon the removal of certain quantities of air from the kiln continuously, either through flues or through accidental leakage. If the air is not allowed to escape at all it will soon become saturated, and no further drying will take place. The steam-spray lines can be replaced by condensers which will serve to cool the air and at the same time remove some of the moisture from it. The cooled air will then naturally fall and pass to the heating coils as fast as the hot air rises from the coils. This natural system of recirculation does not depend upon changing the air in the kiln to remove the moisture evaporated from the wood. Water sprays of the proper temperature may be substituted for the condensers. Water sprays permit a better control of the humidity and may be directed to produce a higher circulation.

The modern blower kiln produces circulation by mechanical means, usually by a centrifugal blower of the ordinary type, but sometimes by disk fans. The blower draws the air from the kiln through suitable return ducts and then discharges it again into the kiln through inlet ducts. The air is passed over heating coils on the way and its humidity is increased, if necessary, by means of a steam jet. Leakage is usually sufficient to keep the humidity as low as desired, but intakes may be provided for drawing a certain amount of fresh air into the system. This fresh air is comparatively dry, and mixing it with the kiln air displaces some of the moist air and reduces the humidity of the whole.

The internal-fan kiln makes use of one or more rows of disk fans within the kiln itself, and thus obviates the necessity of drawing the air from the kiln and blowing it back again. This arrangement has the advantage that the direction of the air circulation may be reversed simply by reversing the direction of rotation of the fans. This reversal of the circulation increases the uniformity of drying in the kiln.

It is difficult to specify the amount of circulation proper for different kinds of drying. For material which has previously been air dried only a small amount of circulation is necessary. For green material, however, or for any drying in which high humidities must be used, a rather rapid circulation is required. There is a limit beyond which the rate of circulation cannot be increased and maintained uniform throughout the kiln. A circulation rate of at least 25 ft. per min. through the lumber is recommended by the U. S. Forest Products Laboratory for difficult drying. In certain unusual cases, as in the drying of Douglas fir common lumber, circulation rates as high as 75 ft. per min. are found desirable. (*Technical Note No. 199 of Forest Products Laboratory*, U. S. Forest Service, Madison, Wis., Aug. 15, 1923, *g*)

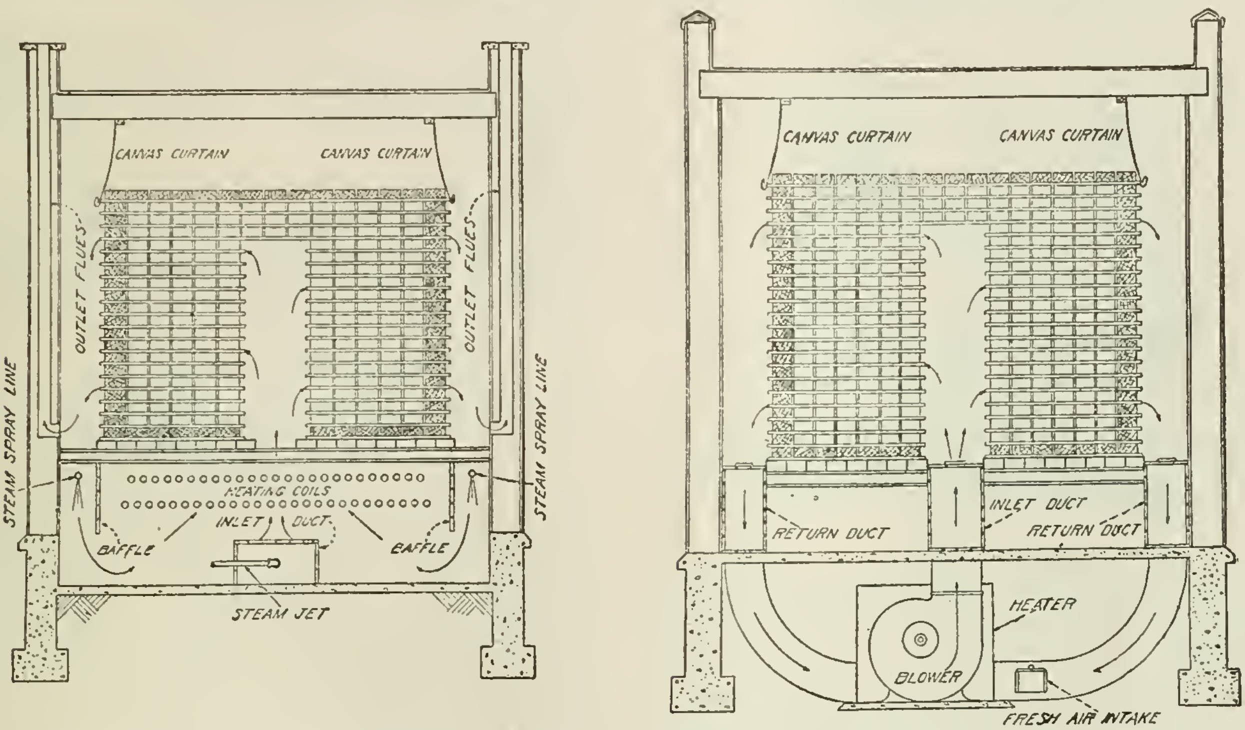

Fig. 1 Types of Ventilated Kilns for Seasoning of Wood

The composite drawing illustrates the various features found in most ventilated kilns. The steam jet in the inlet duct increases the amount of outside air drawn into the system. The steam-spray lines increase the circulation of the air inside the kiln. These spray lines in connection with the inlet ducts and the outlet flues serve to regulate the humidity. The baffles prevent the heated air from rising next to the walls.

The cross-section illustrates the ordinary blower kiln in which an external centrifugal blower produces the circulation. A fresh-air intake on the suction side of the blower can be opened if leakage of air through the walls is not sufficient to keep the humidity below the desired point. Steam jets can be used to raise the humidity if the air gets too dry.

INTERNAL-COMBUSTION ENGINEERING

High-Pressure Oil Engine with Airless Fuel Injection, J. K. E. Hesselman. The Hesselman Diesel engine was briefly described in Mechanical Engineering, vol. 44, no. 8, August, 1922, p. 531, where the details of the fuel-injection valve were given. The present article, however, describes the same engine in considerably greater detail. Among other matters the process of fuel atomization and its mixing with the air together with its subsequent combustion are discussed at length. (*Zeitschrift des Vereines Deutscher Ingenieure*, vol. 67, no. 27, July 7, 1923, pp. 658–662, 16 figs., *d*)

A Diesel Engine of Novel Design

The Knudsen Diesel Engine. An outstanding departure from orthodox design is the adoption in this engine of an inverted V-arrangement of the cylinders and pistons (Fig. 2). Each of the four pairs of V-cylinders has a common combustion chamber with a single injection valve and starting valve. The connecting rods drive parallel crankshafts, one on each side of the engine. At the after end two crankshafts are geared down to a single tail-shaft, the speed reduction being in the ratio of 3.8 to 1.

The engine operates on the two-cycle principle, has a scavenging arrangement comprising exhaust ports in one cylinder and scavenge ports in the other, so that the scavenge air sweeps right through each pair of dual cylinders.

The weight of the 100-b.hp. engine recently completed is about 65 lb. per shaft horsepower. The cylinders are of $6^1/_2$ in. in diameter and have a stroke of 9 in., the crankshafts running at about 400 r.p.m.

The use of a combustion chamber in dual cylinders is not new,

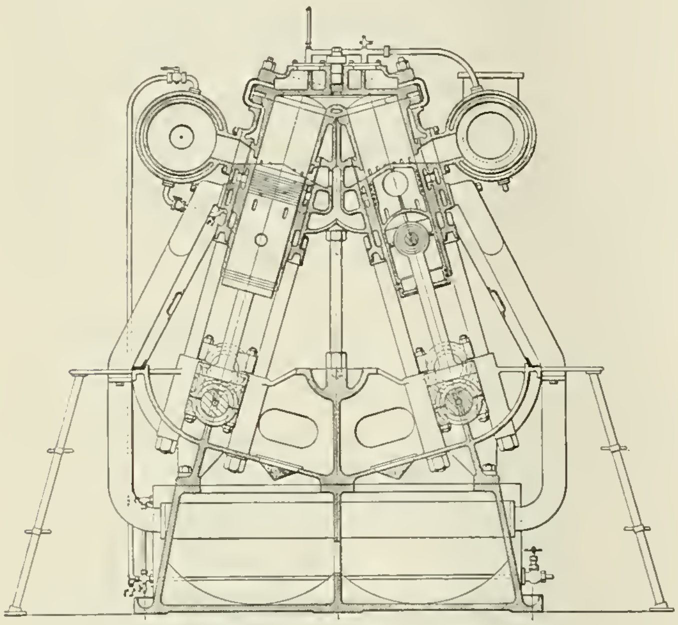

FIG. 2 SECTION THROUGH KNUDSEN DIESEL ENGINE

but the Knudsen engine is said to be the first to combine this feature with an inverted V-arrangement of cylinders and pistons. The engine is of American manufacture. (*Motorship*, vol. 8, no. 8, Aug., 1923, p. 555, 1 fig., *d*)

THE STROMBOLI AERO ENGINE. Peter Hooker, Ltd., of Walthamstow, England, have taken over the British rights for the engine developed by the Italian engineer Stromboli. The engine has been redesigned and developed until it is said today to be virtually a British production. The engine is said to have six cylinders and a total output of 1500 hp. This means 250 hp. per cylinder, which represents a very great advance in aeronautical engineering, as hitherto the greatest output per cylinder—that from the Napier "Cub" engine—has not exceeded some 62 hp. An order has been placed with the manufacturers by the British Air Ministry. (*The Engineer*, vol. 136, no. 3525, July 20, 1923, p. 59, *g*)

MEASURING INSTRUMENTS

OTIS KING CYLINDRICAL SLIDE-RULE CALCULATOR. Description of a calculator of British make. When closed it presents the appearance of a nickel case $1^1/_8$ in. in diameter and $6^1/_4$ in. in overall length. Extended telescope-wise it pulls out to a length of about $10^1/_2$ in. In this condition two spiral scales separated by a sleeve are revealed.

These two scales may be regarded as equivalent to the *A* and *B* scales of an ordinary slide rule, the sleeve representing the cursor and the two indicator marks engraved on it the cursor hairline. The upper scale is twice as long as the lower, but instead of being marked consecutively from 1 to 100, it consists of two identical portions, each covering the range from unity to 10. The lower spiral scale (strictly speaking, that portion of the *A* scale of an ordinary slide rule which extends from unity to the point marked 10) has a total unwound length of about 60 in. and the upper of about 120 in.

The method of operating the calculator and some indication of its accuracy will be gathered by describing a test multiplication made with it. The example chosen was 1.0255 × 1.157, the correct answer to which is 1.1865035. On the ordinary 10-in. slide rule—using the *C* and *D* scales—we can set the sum up as 1.025 × 1.155, the fourth significant figure in each case being estimated. The answer as read is 1.185, the fourth figure again being estimated. On the Otis King calculator the lower indicator mark on the sleeve is set against 1.0255, the fifth significant figure being estimated. The upper tube is then adjusted until the unity mark—either of the first or second half of its scale—registers with the upper indicator mark on the sleeve. This operation is, of course, exactly equivalent to setting the unity mark of the *C* scale of an ordinary slide rule against 1.0255 on the *D* scale. Without moving the relative positions of the two spiral scales the sleeve is now adjusted until its upper indicator mark registers with 1.157 on the upper scale. In this case the fourth significant figure is set up by estimating the mid point between the graduations 1.156 and 1.158. Below the lower indicator mark on the sleeve we read on the lower scale the answer 1.186+. The fourth significant figure is definitely seen to be 6, but the fifth is too uncertain to be estimated. It may be added that five-figure logarithms give the answer as 1.1864, and that six-figure logarithms are required to place the correct value of 5 on the fifth significant figure.

It is important to test the device on the higher portions of the scale as well as upon the lower, and it was therefore tried on the multiplication of 5.435 by 7.375. The ordinary slide rule—*C* and *D* scales—indicates the answer as indistinguishable from 40 dead. The Otis King calculator gives it at 40.1 bare. The correct answer is 40.083.

It seems, therefore, safe to say that this calculator makes it possible in all cases to obtain an answer accurate to one more significant figure than is possible with a 10-in. slide rule. Indeed, its accuracy is very nearly as good as that given by the employment of five-figure logarithms. (*The Practical Engineer*, vol. 68, no. 1898, July 12, 1923, p. 25, 1 fig., *d*)

POWER-PLANT ENGINEERING

Economical Velocity of Superheated-Steam Flow in Piping Systems Supplying Turbines

THE INFLUENCE OF VALVES AND STEAM TRAPS ON THE ECONOMIC STEAM VELOCITY FOR SUPERHEATED-STEAM TURBINES, Prof. O. Denecke. The present article is based on a previous publication by the same author in the German journal *Die Wärme*, no. 8, 1922, under the title The Most Economical Pipe Diameter for Superheated-Steam Plants. It discusses the upper limits of economic steam velocity and in particular the influences which affect the pipe diameter in a superheated-steam plant.

The author's opinions are all based on formulas developed in the article above referred to for the "least" diameter of the steam pipe d_D, which is the diameter insuring the smallest steam consumption, and his formula for the most economical diameter d_b, at which the yearly costs for steam consumption and capital charges are the smallest.

By applying the author's formula to the usual field of superheated-steam turbines it becomes possible to determine the limits of the most desirable steam velocity v_D corresponding to the steam-flow diameter d_D and also to determine the velocity v_b corresponding to the pipe diameter d_b. The author considers in particular the region determined by the following values:

Steam pressure p_a = 16 atmos. and 10 atmos.
Steam temperature t_a = 350 deg. cent.
Output N = 8500 kw. with a steam consumption G = 45,000 kg. per hr. and 750 kw. with a steam consumption G = 5000 kg. per hr.

The author states that his formula and examples show that:

1 The velocities for the smallest steam-flow diameter v_D are lower than the velocities v_b, which latter take into consideration the capital charges in addition to the steam consumption. But even these latter velocities are much lower than the values often quoted in technical literature such as 80 to 100 m. per sec. (262.4 to 328 ft. per sec.). As a matter of fact, even in the most favorable cases, which occur quite seldom, v_b = 48 m. per sec. (157.5 ft. per sec.)

2 The economical velocity of steam v_b is the higher
a The higher the steam temperature t_a
b The lower the boiler pressure, and
c The smaller the turbine.

3 For a turbine of a given output N, a given steam pressure p_a, and a given steam temperature t_a, the economical velocity of steam is the higher the smaller the sum of individual resistances, $\Sigma\zeta$, corresponding to 1 m. (3.28 ft.) of the total length of piping

(l). Since in well-arranged piping the individual resistances consist mainly of valves and steam traps, it would appear that the velocity of steam and the pipe diameter are determined practically exclusively by the number of resistances and the cost of the steam shutting-off devices.

In order to make clear the remarkable influence of these devices, four cases have been investigated dealing with two sizes of turbines having outputs N = 8500 kw. and N = 750 kw., and two initial steam pressures p_a = 16 atmos. and 10 atmos. with the same steam temperature 350 deg. cent. It is also assumed that the total length of the piping is the same, namely, l = 50 m. (164 ft.).

The author then proceeds to consider the question of costs under conditions prevailing in Germany during the first quarter of 1920. These values appear in Figs. 3 and 4 and they indicate the great influence which resistance in the valves has on the economic dimensions of piping or the velocity of steam flow. If we consider as a standard the most favorable case, namely Case 1, with two Koswa valves of low resistance to flow and no steam trap, it would appear that Case 3, in which ordinary valves are used, would require an increase of the diameters d_D and d_b (columns 7 and 9 of Table 1) by 23 per cent, corresponding to a reduction in the velocity of steam from 100 per cent to 64 per cent (columns 8 and 10). If, however, steam traps are provided which have a high resistance to flow (ζ = 7), the difference becomes much smaller, a comparison of Cases 2 and 4 showing only an increase of diameter from 115 per cent to 132 per cent (columns 7 and 9).

In general, it would appear that

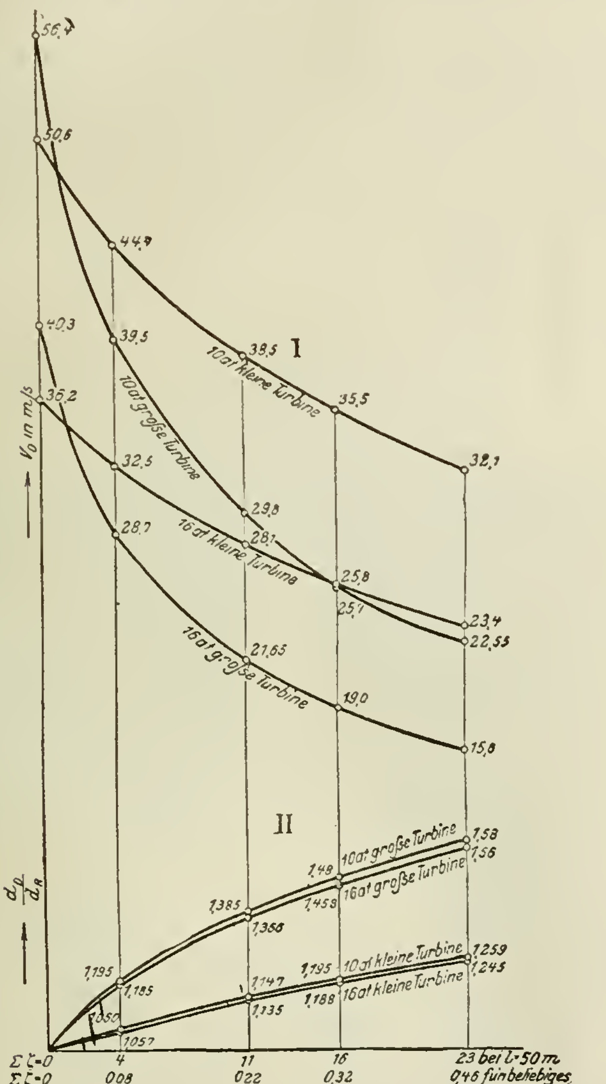

Fig. 3 I—Velocity v_D for the Smallest Steam Consumption as Function of Pressure p_a and Individual Resistances $\frac{\Sigma\zeta}{l}$ at the Temperature t_a = 350 Deg. Cent.

II—Increase of the Most Favorable Pipe Diameter d_D as a Result of Increase in Individual Resistances Represented by the Ratio $\frac{d_D}{d_R}$ in Functional Dependence Upon $\frac{\Sigma\zeta}{l}$

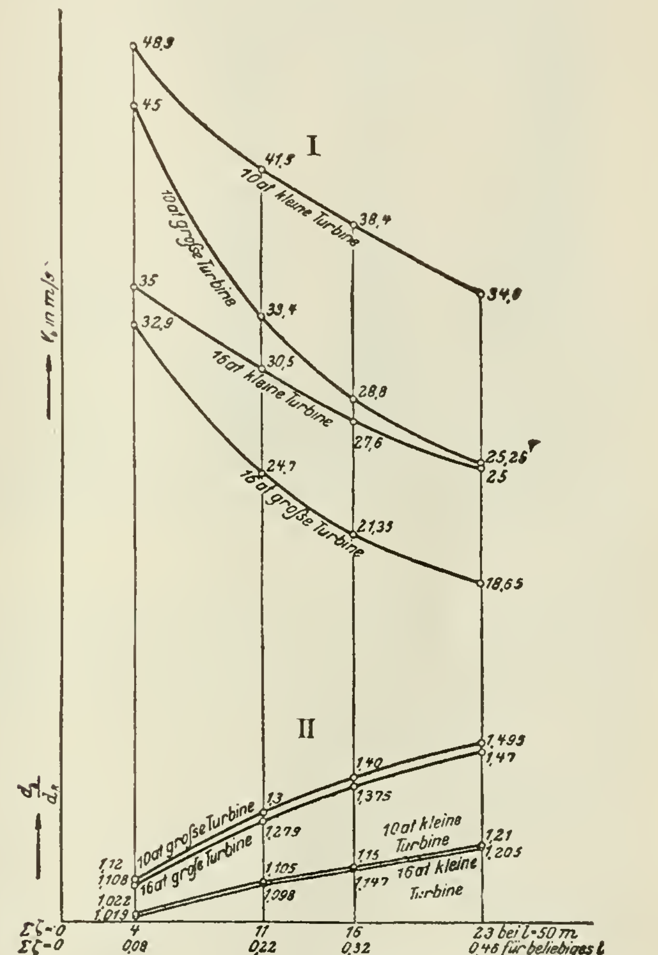

Fig. 4 I—Velocity v_b as Result of Use of the Most Economical Pipe Diameter d_b as a Function of Pressure p_a and Individual Resistances $\frac{\Sigma\zeta}{l}$ at Temperature t_a = 350 deg. cent.

II—Increase in the Most Economical Pipe Diameter d_b Produced by Increase in Individual Resistances Represented by the Ratio $\frac{d_b}{d_R}$ in Functional Dependence upon $\frac{\Sigma\zeta}{l}$

At kleine Turbine = atmospheres, small turbine; *at grosse Turbine* = atmospheres, large turbine; *Koswa-Ventile* = Koswa valve; *norm. Ventile* = ordinary valve; *ohne Wasserabsch.* = without steam trap; *mit Wasserabsch.* = with steam trap; *bei* = at; *für beliebiges l* = for any l.

Case 1. The sum of the individual resistance $\Sigma\zeta$ = 4. This arrangement contains two modern valves with low resistance to flow (ζ = 1) and there are a few bends in the piping. As an example of a modern valve the author mentions the Koswa, which is built by several concerns in Germany.

Case 2. $\Sigma\zeta$ = 11. Here there are two Koswa valves (ζ = 1), a few bends, and in addition a large steam trap (ζ = 7).

Case 3. ζ = 16. This arrangement comprises two ordinary valves offering a large resistance to flow (ζ = 7) and a few bends.

Case 4. $\Sigma\zeta$ = 23. In this case there are two ordinary valves (ζ = 7), a few bends, and a large steam trap (ζ = 7).

1 A reduction of the individual resistances in piping effected by replacing ordinary valves by Koswa valves is the more advantageous the lower are the other individual resistances in the installation; and that

2 Steam traps with their present construction and high resistances to flow are particularly unfavorable.

It is worth noticing that the economical velocities of steam are comparatively low, in any event lower than those usually assumed. At high pressures ($p_a \leqq$ 16 atmos.) and with large turbines the most economical steam velocities are $v_b \leqq$ 32.8 to 35 m. per sec. (107.62 to 114.82 ft. per sec.), and for the case of ordinary valves

TABLE 1 DIAMETER OF PIPING IN SUPERHEATED-STEAM PLANTS AND ECONOMICAL VELOCITY OF STEAM AS AFFECTED BY STEAM VALVES AND STEAM TRAPS

1	2	3	4	5	6	7	8	9	10	7a	8a	9a	10a
	Valves					Large Turbine, Steam Consumption G = 45,000 kg. per hr.				Small Turbine, Steam Consumption G = 5000 kg. per hr.			
Case	Number and kind	Resistance factor	Resistance factor of steam trap	Other resistances	$\Sigma\zeta$ Columns 3, 4, 5	d_D per cent	v_D m. per sec. = per cent	Most economical diameter d_b per cent	Most economical velocity v_b m. per sec. = per cent	d_D per cent	v_D m. per sec. = per cent	Most economical diameter d_b per cent	Most economical velocity v_b m. per sec. = per cent
	Initial Pressure p_a = 16 atmos. abs.												
1	2 Koswa valves	2 × 1	–	2	$\Sigma\zeta = 4$; $\frac{\Sigma\zeta}{l} = 0.08$	100	28.7 = 100	100	32.9 = 100	100	32.5 = 100	100	35 = 100
2	2 Koswa valves	2 × 1	7	2	$\Sigma\zeta = 4$; $\frac{\Sigma\zeta}{l} = 0.22$	115	21.65 = 75.5	115.2	24.7 = 75	107.5	28.1 = 86.5	108	30.5 = 87.3
3	2 Ordinary valves	2 × 7	–	2	$\Sigma\zeta = 16$; $\frac{\Sigma\zeta}{l} = 0.32$	123	13.0 = 66.4	124.1	21.35 = 64.6	112.5	25.8 = 79.5	113	27.6 = 29
4	2 Ordinary valves	2 × 7	7	2	$\Sigma\zeta = 23$; $\frac{\Sigma\zeta}{l} = 0.46$	131.6	16.6 = 57.8	133	18.65 = 56.6	118	23.4 = 72	118	25 = 71.5
	Initial Pressure p_a = 10 atmos. abs.												
1	2 Koswa valves	2 × 1	–	2	$\Sigma\zeta = 4$; $\frac{\Sigma\zeta}{l} = 0.08$	100	39.5 = 100	100	45 = 100	100	44.7 = 100	100	48.3 = 100
2	2 Koswa valves	2 × 1	7	2	$\Sigma\zeta = 11$; $\frac{\Sigma\zeta}{l} = 0.22$	116	29.8 = 75.5	116	33.4 = 74.3	108	38.5 = 86	108	41.5 = 86
3	2 Ordinary valves	2 × 7	–	2	$\Sigma\zeta = 16$; $\frac{\Sigma\zeta}{l} = 0.32$	124	25.7 = 65.1	125	28.8 = 64	113	35.5 = 79.5	112.8	38.4 = 79.5
4	2 Ordinary valves	2 × 7	7	2	$\Sigma\zeta = 23$; $\frac{\Sigma\zeta}{l} = 0.46$	132	22.5 = 52.5	133	25.3 = 56.2	119	32.1 = 71.7	118.5	34.6 = 71.6

with steam traps these reduce to $v_b \leq$ 18.65 to 25 m. per sec. (61.16 to 82 ft. per sec.). Only the higher values are to be used for small turbines. The lower the initial steam pressure p_a the higher are the steam velocities, but even at p_a = 10 atmos., and in the most favorable case (Case 1), these velocities reach only the value v_b = 45 to 48.3 m. per sec. (147.63 to 158.45 ft. per sec.) or far below the values of 80 to 100 m. per sec. (262.4 to 328 ft. per sec.) recommended in technical literature. (*Der praktische Maschinen-Konstrukteur*, vol. 56, no. 15, Apr. 26, 1923, 3 pp., 2 figs., *t*)

Grjimailo's Hydraulic Theory of Boiler-Furnace Design

Modern Boiler Furnaces from the Point of View of Theory of Furnaces Based on the Laws of Hydraulics, W. E. Groume Grjimailo. Criticism of the design of the pulverized-coal-burning furnaces of the River Rouge plant of the Ford Motor Co. as described in a paper by H. D. Savage read before the American Iron and Steel Institute, May 27, 1921.

This furnace (Fig. 5) embodies, according to the author, a series of cumulative errors from the point of view of furnace theory based on the laws of hydraulics. These errors he points out in order to give an example of rational criticism of present-day constructions.

1 The flattened-out burner of the boiler furnace is very interesting. The atomization of the fuel is carried out by means of steam. In order not to lower the temperature of the combustion chamber it would be better to employ for this purpose compressed air at the same pressure as the steam in the boiler. The secondary air might be supplied to the burner preheated. The use of preheated air in pulverized-coal furnaces was adopted in Russia in 1918 and has given excellent satisfaction.

2 It is quite rational to direct the atomizing burner downward. Since the direction of the flame is inverted, the products of combustion because of their low specific gravity take an upward course in countercurrent to new quantities of the mixture of coal dust and air. This mixture ignites easily and the succession of reactions of combustion is not disturbed.

3 It is wrong, however, to locate the burner along the walls as this increases the depth of descent of the jet of incandescent gas and as a consequence increases the height of the combustion chamber. The author believes that in a rationally designed combustion chamber the jet of dust may be burned entirely out of contact with the walls of the combustion chamber. The quantity of ashes coming from pulverized coal and accumulating in the combustion chamber will be greater in the case where the flame jet does not reach the bottom of the chamber.

4 The construction of the combustion chamber of the River Rouge power plant is not rational. As the author has shown in his book The Flow of Gases in Furnaces (English translation, New York, 1923), the combustion chamber must represent a pocket of hot gases. The flame elements should stay below the combustion chamber for a period of at least 1½ sec., and it is only then that they may be allowed to pass through the ports in the hearth. The combustion chamber at the River Rouge plant is not designed to insure complete combustion of the dust, and it is to this fact of incorrect design that are due the excess of air used (15 to 30 per cent) and the high content of unconsumed carbon in the ashes (up to 9.52 per cent). It is obvious that in that furnace the flame reaches the interior of the boiler before the reactions of combustion have been completed, is cooled through contact with the cold tubes, and as a result of this the combustion cannot be completed with only a slight excess of air.

5 The flues of the River Rouge boiler are said by the author to be designed in an incorrect manner. By virtue of the theory of furnaces built in accordance with the laws of hydraulics, the streams which are cooled should be directed downward. It is only in such a case that one may expect that the cold boiler tubes would be uniformly enveloped by the gases of combustion and that the heat convection would be complete. The presence in the brickwork of a whole series of baffles tending to change the direction of the flames, indicates that the gases of combustion do not have the tendency to circulate along the tubes and that they are forced to do so merely by the chimney draft.

After this critical review of the River Rouge furnace, the author proceeds to present a design for the reconstruction of this furnace which would bring it in accord with the "hydraulic theory." This design is shown diagrammatically in Fig. 6.

1 The combustion chamber AA represents a "pocket" of hot gases. At the peak of the roof of this furnace is located the burner B giving the downward vertical jet.

2 Since the walls of the combustion chamber might suffer from the high temperature consequent on such a construction, passages C are provided in these walls and are utilized to preheat the secondary air supplied at a low pressure to the burner B.

3 The dimensions of the combustion chamber AA must be suited to the type of burner. The burner must be tested before the combustion chamber has been built, and the dimensions selected for the combustion chamber must be such as will enable it not only to contain the flame cone but also to provide space in which the products of combustion may rise freely along the walls of the combustion chamber and leave it through the ports D.

4 The ports D should be computed in accordance with the Yesmann's formula:

$$h = A^3 \sqrt{\frac{O^2}{B^2 t}}$$

5 The incandescent gases should rise to the chambers F_1 and F_2 where the boilers are located.

Contrary to the usual custom but in conformity with the hydraulic theory, the author would incline the boiler tubes toward the flues rather than toward the furnace. It is obvious, of course, that with the tubes thus inclined there is no need to provide baffles in order to force the incandescent gases to envelop the tubes and give up to them their heat.

6 With the arrangement described above we then have cold vertical tubes located in an atmosphere of stationary incandescent gases. Near the surface of the tubes there is a layer of products of combustion which will give up its heat to the tubes and will be cooled to the temperature of the latter.

As soon as the layer of gases in contact with the tubes is cooled down, it obviously cannot remain in equilibrium in an atmosphere of the lighter furnace gases. It begins to descend and a quantity of incandescent furnace gases comes to take its place. These new gases in their turn are cooled down and, becoming heavier, move downward along the tubes. In this manner, quite naturally and without the assistance of any baffles whatsoever, there is established in the confines of the boiler the following circulation of gases:

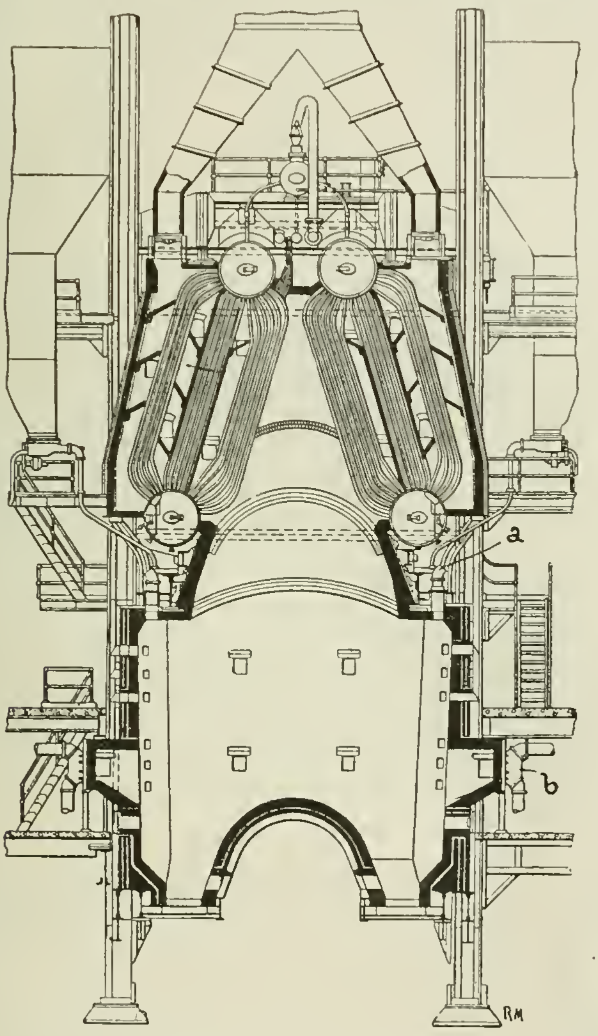

Fig. 5 Boiler Installation at the River Rouge Plant of the Ford Motor Co.
(a—Pulverized Coal; b—Gas Burner.)

a The furnace gases rise toward the roof of the boiler chambers F_1 and F_2 through the ports D;

b Through coming in contact with the boiler tubes, these gases are cooled and then move downward;

c By placing the flue ports g_1 and g_2 near the bottom of the combustion chambers F_1 and F_2 and by giving the boilers a slight incline toward these ports, it is possible to secure an absolutely correct circulation from top to bottom in which the colder gases flow toward the flues without the employment of any baffles, without in any way interfering with their employment, without restricting the uniformity of this movement, and without disturbing the regularity of heat transmission from the gases to the boiler walls.

One may make use of the formula of vertical gas jets:

$$h = \frac{V^2}{2g} \times \frac{273 + ti}{tm - ti}$$

by introducing into it a correction coefficient. This coefficient

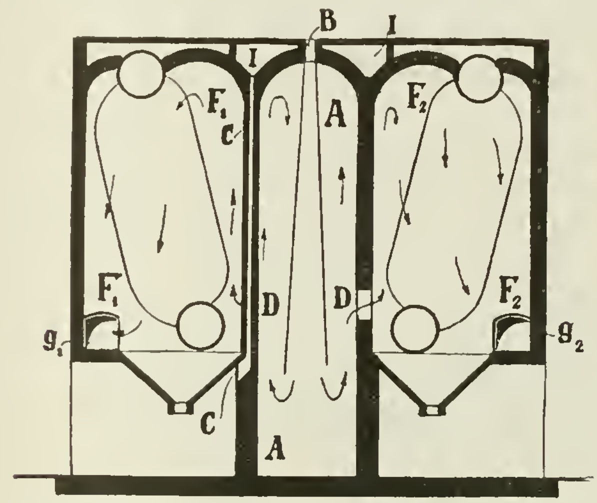

Fig. 6 Diagrammatic Design of the Installation Shown in Fig. 5, Bringing It in Conformance with the Author's Hydraulic Theory of Furnace Design

was found to be equal to 0.7 by the engineer Slessareff, who has made a special study of this subject at the Polytechnic School at Petrograd. With this value one is enabled to establish the formula for the velocity of circulation of gaseous streams along the boiler tubes, namely,

$$V = \sqrt{0.7 \frac{tm - ti}{273 + ti} 2gh}$$

Assuming that $tm = 1100$ deg. cent. and $ti = 300$ deg. cent.,

$$V = 0.64 \sqrt{2\,gh}$$

As in this case the length of the boiler tubes is 5.3 m. (17.4 ft.) the velocity of descent of the cold gas streams is found to be equal to

$$V = 0.64 \sqrt{2 \times 9.81 \times 5.3} = 6.5 \text{ m. per sec.}$$

It would appear, therefore, that the velocity of the small streams at the top near the walls of the main body of the boiler is close to zero. At the bottom toward the cylindrical bottom of the boiler this velocity becomes equal to 6.5 m. (21.3 ft.) per sec.

Knowing the quantity of gases of combustion reaching the boiler chamber, it becomes possible to calculate the thickness of the layer of gas surrounding each tube. According to the author's calculation it does not exceed 25 mm. (1 in.).

7 The water circulation in the boilers takes place in the ascending direction from the lower cylindrical drum toward the main upper boiler, i.e., opposite to the direction of the circulation of the hot gases. This creates exceedingly favorable conditions for the convection of heat.

8 In conclusion, the author discusses briefly the preheating of air. In the design of boiler under consideration the air is taken in through openings in the manholes provided for cleaning the boiler. It then rises through the vertical passages CC provided in the walls of the combustion chamber and finally reaches the collector passages II. Its pressure in the upper passages become

equal to that of the atmosphere so a blower may be dispensed with by selecting the proper type of burner. However, it is a more certain process to take the air from the passages *H* by means of a blower and thus deliver it to the pulverized-coal burners. The author believes the use of hot air would make it possible to burn coarse pulverized fuel and use equally well dry coals or those containing considerable moisture. (*Revue de Métallurgie*, vol. 20, no. 3, March, 1923, pp. 189–192, 2 figs., *t*)

Central Station Using Steam at 1200 Lb. Pressure

New Extra-High-Pressure Steam Station, I. E. Moultrop and Joseph Pope, Members A.S.M.E. Description of the Weymouth Fore River Station of the Edison Electric Company of Boston, of interest because it includes a boiler working at a pressure of 1200 lb. per sq. in.

Steam from this extra-high-pressure boiler will first pass through a turbine developing about 200 kw., whence it will be exhausted at 375 lb. pressure. It will then be reheated to 700 deg. fahr. and sent on the larger turbines.

Reheating of the steam is essential if the full benefit is to be obtained; without it the most economical top pressure seems to be 375 lb. The feedwater is to be heated by two-stage bleeding of the main units and by economizers. All the ordinary auxiliaries are to be driven by alternating current derived from a 2500-kva., 2300-volt alternator, direct coupled to the main generator shaft of each 30,000-kw. turbo set, which, with the 2500-kva. alternator, totals some 32,000 kw.

It is hoped that this combination of 1200-lb. and 375-lb. sets will yield a kilowatt-hour for 13,600 B.t.u.

The 1200-lb.-pressure boiler will, like the lower-pressure (375 lb.) boilers, have a heating surface, of 19,743 sq. ft. It will have its own economizer, superheater, and resuperheater. All boilers will be fired by underfeed stokers.

Now for the question of total heat and efficiency possible. In Fig. 7 curve No. 1 shows the total heat above 79 deg. fahr. in 1 lb. of steam at a uniform temperature of 700 deg. fahr., 79 deg. being the temperature corresponding to 1 in. absolute pressure. It will be noted that the total heat shows a decrease with increasing pressure.

Curve No. 2 shows the heat remaining in the steam after perfect adiabatic expansion from the stated initial conditions to a pressure of 1 in. abs. The vertical distance between this curve and curve No. 1 accordingly represents the B.t.u. per lb. of steam theoretically available for doing work.

Curve No. 3 is a plotting of the available heat as a percentage of the total heat shown by curve No. 1 and represents the efficiency of the Rankine cycle at varying pressures. Its upwardly convex curvature indicates how the rate of increase in theoretical efficiency diminishes with increasing pressure.

Curve No. 4 shows the best efficiency at present to be expected of turbo-generators in converting the available heat, as shown by curve No. 3, into useful electrical energy. In determining this curve the unit is credited with all heat recovered in the condensate by bleeding at two stages.

Curve No. 5 is the product of curves Nos. 3 and 4 and indicates, for the different pressures, the percentage of the total initial heat in the steam which would be actually converted into electrical energy or returned to the boiler in the condensate. It will be noted that this curve takes the shape of a dome with its highest point corresponding to a steam pressure of about 600 lb. abs.

If steam turbines could be constructed which would be equally efficient in transforming the available heat energy into useful work under all conditions of initial steam pressure, curve No. 3 would indicate that the overall thermal efficiency would increase with the pressure throughout the entire range considered. The most important factors which act to decrease the turbine efficiency at higher steam pressure are the increased gland and interstage leakage losses and, more particularly, the increased steam friction occasioned by the entrained water after the dewpoint has been reached. This lowered efficiency is particularly marked where the maximum permissible total temperature causes the higher pressures to be accompanied by diminished superheat, thus advancing the dewpoint to an earlier stage. The recognized method of meeting this difficulty, and thus permitting the superior possibilities of higher steam pressures to be realized, is to interrupt the expansion of the steam at some intermediate pressure and restore its temperature by reheating before the expansion is continued. This may be accomplished either by employing two independent turbines, one exhausting to the other through the reheater, or by returning the reheated steam to the lower stages of the same machine from which it was extracted. The design of the Weymouth station makes provision for employing the former of these two methods, using a maximum pressure of 1200 lb.

The high-pressure boilers will have tubes 2 in. in outside diameter and 15 ft. long. The tubes will be arranged in ttwo banks with sufficient space between for the superheater and reheater. The drum will be a hollow steel forging 48 in. in outside diameter with walls 4 in. thick. In order to maintain suitable drum strength

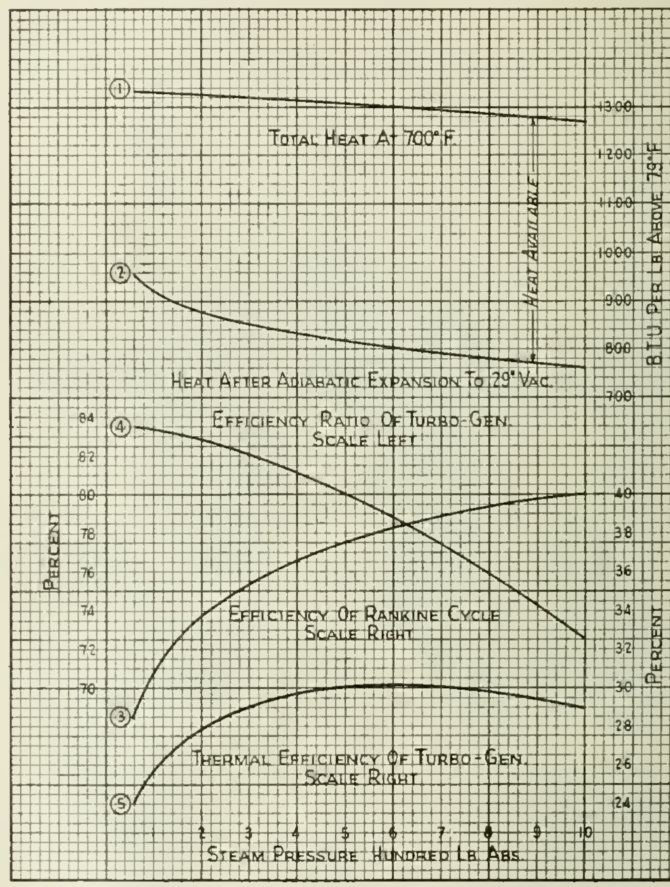

Fig. 7 Effect of Steam Pressure on Turbine Thermal Efficiency

the tubes and nipples, which commonly enter the drum in lines parallel with its axis, are turned in pairs through an angle of 90 deg., so that the two enter the drum on a common circumference. Make-up water is to be provided by evaporators, and the whole supply will be deaerated.

An article in the *Electrical Times* (vol. 63, no. 1654, June 28, 1923, pp. 677–679), in commenting upon this paper, states as follows:

"So here we see that the steam generated at 1200 lb. and used at 1000 lb. only means an extra $2^1/_2$ per cent in efficiency, which is not exactly a sumptuous gain, and must be considered in its commercial relation to the extra cost of plant. But we must by no means thrust it aside and leave it at that; there are too many hard-headed experimenters and business firms at work on it to allow us for one moment to regard this as a chimera. Dr. Ferranti believes that we are in view of an overall thermal efficiency of 30 per cent. And in saying this he has in mind only steam boilers and turbines; he would no doubt allow that other combinations are conceivable." (Paper presented at the 1922 Spring Meeting of The American Institute of Electrical Engineers, abstracted through *The Electrical Times*, vol. 63, no. 1654, June 28, 1923, pp. 677–679, 3 figs., *d*)

A Combined Cylindrical and Water-Tube Boiler

The Hudson Boiler. Description of a boiler which is a combination of the cylindrical and water-tube. It is made in two distinct types. For large evaporators the cylindrical element consists of a short two-flued boiler of the Lancashire type, while for smaller requirements it is of the single-flued or Cornish type. In either case the cylindrical element is flanked on each side with the nest of water tubes set low down in the front and rising toward the back end of the boiler. The bottom header of each nest of tubes is connected by a mild-steel pipe of large capacity to the drum at the fore end of the cylindrical elements. This simple means of combining two distinct types of boilers in one unit results in a very powerful steam generator, which, while retaining the simplicity of the cylindrical boiler, gives a very much higher efficiency.

The passage of the gases through the boiler is by means of the internal furnace flue until they reach the back end of the cylindrical element. From this point they pass through a port into side flues and sweep along and over the water tubes and also along the side of the cylindrical element, after which they pass into the main flue under the boiler. The position of the tubes is therefore such that they are not exposed to intense local heat as the gases do not come into contact with them until after they have passed through the length of the internal flues of the cylindrical element (Fig. 8). The circulation of the water in the boiler is obtained by feeding the water through the front end. The cold water flows to the bottom of the cylindrical element and then passes through the connections into the bottom drums of the water-tube elements, passing up the tubes where it is met by the gases flowing in the opposite direction, the steam formed making its way up the inclined tubes to the back header and then into the steam space of the cylindrical element. Because of this there is a definite circulation of water in the cylindrical element of the boiler, which insures uniformity of temperature.

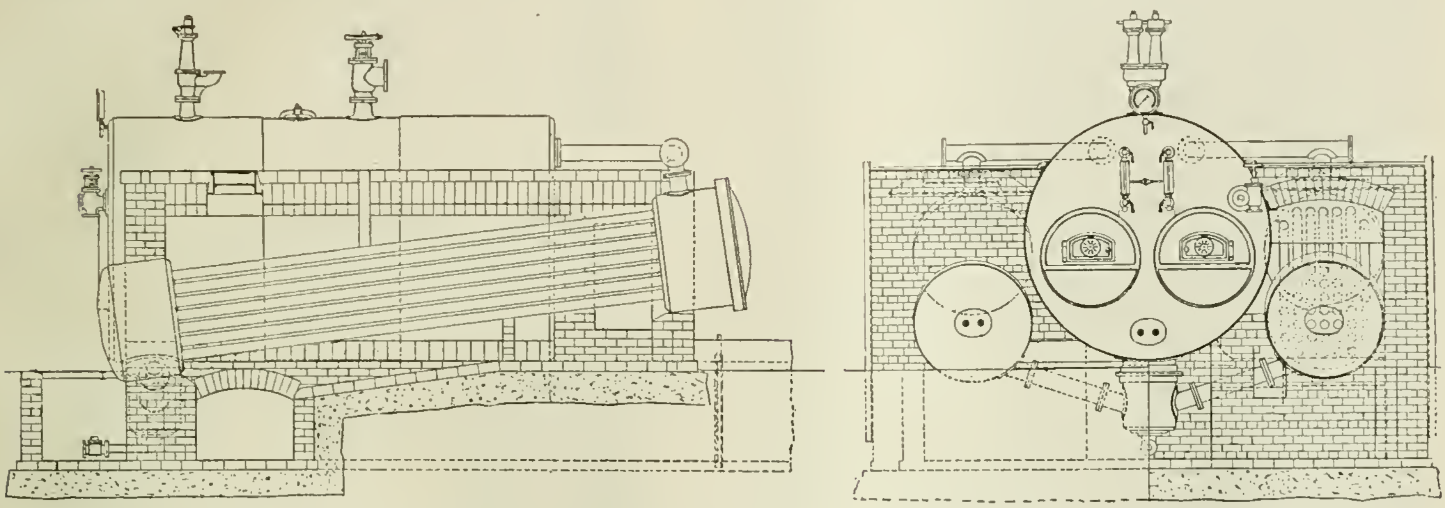

Fig. 8 Hudson Combined Cylindrical and Water-Tube Boiler

TABLE 2 EVAPORATIVE TEST ON TWO HUDSON PATENT CYLINDRICAL AND WATER-TUBE BOILERS AT THE WORKS OF THE ROSE PATENT FUEL COMPANY, LTD., SWANSEA

Heating surface of each boiler, sq. ft	2470
Grate area of each boiler, sq. ft	45.5
Ratio of heating surface to grate area	54 to 1
Duration of test, hr	5
Boiler pressure (gage), lb. per sq. in	155.5
Boiler pressure (absolute), lb. per sq. in	170.0
Temperature of feedwater to boiler, deg. fahr	43
Temperature of steam leaving superheater, deg fahr	590
Total weight of feedwater during test, lb	95,550
Factor of equivalent evaporation (boiler only)	1.224
Factor of equivalent evaporation (including superheater)	1.347
Weight of feedwater per boiler per hour, lb	9555
Equivalent evaporation from and at 212 deg. fahr., lb	12,870
Fuel used during test	Rose patent fuel briquets
Heating value of fuel per lb., B.t.u	13,568
Total weight of fuel burned, long tons	5.1
Weight of fuel burned per boiler per hour, lb	1154
Water evaporated per lb. of fuel burned, lb	8.28
Equivalent evaporation per lb. of fuel from and at 212 deg. fahr., lb	11.15
Temperature of escaping gases taken at chimney, deg. fahr	473
Draft in inches of water	0.92
Percentage of ash and clinker to total weight of fuel used during test	8.84
Boiler efficiency, per cent	80

The results given in Table 2 of an evaporative test would indicate that with this type of boiler the economizer can be dispensed with. (*The Iron and Coal Trades Review*, vol. 107, no. 2889, July 13, 1923, p. 40, 1 fig., *d*)

Steam Accumulators, M. Emanaud. General considerations on the subject, together with descriptions of the Halpin, Morison, Rateau, and Ruths accumulators, and a bibliography on the subject. The various types are illustrated. The Ruths accumulator was described in Mechanical Engineering, vol. 44, no. 5, May, 1922, pp. 323–324. The other accumulators are well known.

The following comparison of types may be of interest. The apparatus of the gas-holder type can be charged most rapidly, as there is no necessity in this apparatus for mixing to obtain a uniform temperature. That is because an absence of uniform temperature in this apparatus will have no effect on its ability to absorb steam, which is the case with all apparatus in which the steam is condensed in the water. This sort of apparatus also maintains a steadier pressure and hence has less influence on the machinery supplied by it with steam.

On the other hand, these bell accumulators are more bulky than the water type, because the uncondensed steam has a much greater volume in comparison to the steam when condensed in water. The advantage obtained here, however, is not so much as one might at first believe, because the water-reservoir type of accumulator necessitates the storage of a large volume of water which is to be transformed into steam during the accumulator's discharge.

Supervision is much easier and heat insulation is much less expensive in the water-reservoir type of apparatus than in the gas-holder type, because in the first type there are no moving parts. The latter type of accumulator, when well designed to insure a uniform temperature and to avoid violent ebullition, is a machine of definite functioning qualities which permits remote control and needs a minimum operating force.

The degree of saturation of the steam supplied by accumulators depends not only on more or less regular ebullition and release of steam in the apparatus, but also on the fall in pressure obtained in the reducing valve at the outlet. (*Chemical and Metallurgical Engineering*, vol. 29, no. 4, July 23, 1923, pp. 149–152, 10 figs., *dc*)

RAILROAD ENGINEERING

Transverse Fissures in Steel Rails

A Study of Transverse Fissures in Steel Rails, James E. Howard. The article here abstracted is itself an abstract from a report made to the Interstate Commerce Commission by the author who is engineer-physicist of that body.

A transverse fissure as a specific type of fracture was first recognized in a report to the Interstate Commerce Commission dealing with an accident which occurred in 1911. The term applies to a type of fracture which has its origin in the interior of the head of a rail and which progressively enlarges from a definite nucleus.

The plane of rupture is here crosswise the length of the rail and substantially perpendicular to its axis. Transverse fissures have an interior origin, because the metal immediately below the running surface of the head is in a state of compression due to the cold-rolling effects of the wheels.

The number of transverse fissures considered in this report exceeds 8000, this being only a partial list of the total number of fissures which are a matter of record. They occurred in rails coming from every rail mill in the country, and in numbers predominated on trunk lines of high speed, heavy equipment, and congested traffic. It appears that transverse fissures in larger numbers on the gage side of the head of the rail than over the web or in the outer half of the head.

Transverse fissures being of progressive formation, their final stage of development may occur at any time. The length of time required for incipient fissures to make their presence known depends upon the amount and character of traffic carried by the rails. It does not appear that the appearance or absence of transverse fissures depends on the part of the ingot that the rail comes from.

A somewhat different feature is presented in the consideration of the ages of rails with respect to their ingot positions over that of their numerical relations. Rails which fractured in largest numbers during the first few years in the track came from those parts of the ingot which are generally conceded to be the best. Rails from segregated parts were fewer in number. These results cast a doubt upon the validity of connecting the formation of transverse fissures with the segregated parts of the ingot.

The average ages of transverse fissures on different railroads in the main reflect traffic conditions. Weights of equipment, gross tonnage, and speeds are the prominent features which characterize the conditions on those roads where maximum numbers and minimum ages of fissured rails appear.

While there is no known reason why bessemer and open-hearth rails should not behave substantially alike in respect to the formation of this kind of fracture, their comparative absence in bessemer rails has been noted.

Transverse fissures have also been produced experimentally by subjecting rails to treatment analogous to the cold-rolling action of wheels. This result was accomplished by repeated alternate overstraining of the rail longitudinally. Half-length rails were used, applying gagging blows at short intervals along the length of the head, then reversing the bend and gagging the base in the same manner. This alteration of reversed bending was continued until ultimate rupture ensued.

The position of the interior fissure was found controllable at will. Gagging the rail in upright position yielded a transverse fissure centrally over the web; inclining the rail to the right or to the left and applying the gagging blows in an oblique direction yielded transverse fissures located in the right or left side of the head, whichever way the rail was canted.

Broadly considered, three features constitute the rail problem: (1) Girder strength; (2) abrasive resistance to the action of wheels; (3) cold-rolling effect of wheels on the head of the rail. If the third feature was eliminated there would be no rail problem, since the requirements of the first and second can be met without difficulty.

The most obvious deduction to be made from this compilation of data on the display of transverse fissures is the apparent close approach to the limit of endurance experienced by rails under the conditions of service which now prevail on the trunk lines of the country. The prevalence of transverse fissures reached a degree of magnitude some time ago, when serious and concerted action should have been taken to study the influences which affect the state of the metal of the rail in the upper part of the head, upon which rests the responsibility for the formation of transverse fissures. The ideal manner of advancing this subject would be through the coöperation of the trunk-line railroads and the steel mills. (*Railway Age*, vol. 75, no. 5, Aug. 4, 1923, pp. 210–212, *g*)

SPECIAL PROCESSES

Drying Equipment in an Artificial-Leather Plant

Chemical Engineering in the Production of Coated Fabrics, Sidney D. Kirkpatrick. Description of the manufacture of artificial leather and rubberized cloth at the plant of the Duratex Corporation, Newark, N. J. Of particular interest is the way in which the problem of air drying has been solved.

This drying equipment is an especially interesting application of air drying under rather unusual conditions. It is necessary to provide facilities for drying the base coating as rapidly as possible, and, at the same time, to remove the solvent vapors effectively, in order to keep explosion and fire hazards at a minimum. The system was designed and installed by the Carrier Engineering Corporation and makes use of the ejector principle for efficient circulation of the air. As may be seen from the plan and elevation shown in Fig. 9, it is designed according to well-known countercurrent principles. The air is delivered from the ejector nozzles at a velocity of approximately 1000 ft. per min., and passes over the driest cloth as it is on its way out of the drying chamber. In counter-direction the air then passes around the entire path covered by the cloth and is finally exhausted at an outlet directly beneath the coating head of the machine. The air current divides at the base of the fan and a part

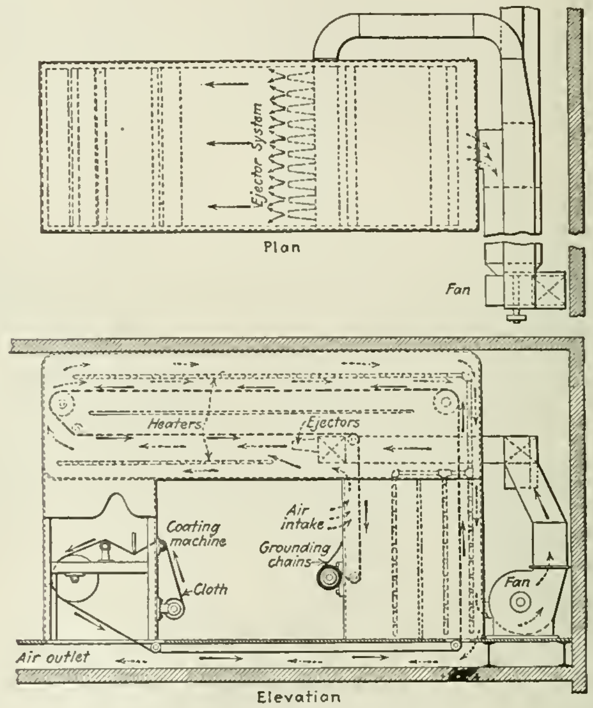

Fig. 9 Plan and Elevation for Drying Equipment for Pyroxylin Coating Machines

of the heated air is drawn into the fan to be recirculated directly by the ejector nozzles.

The apparatus handles about 2500 cu. ft. of air per min. for each of the coating machines. The temperature is maintained at approximately 175 deg. fahr. depending upon the amount of air handled and how vigorously it is circulated. The drying chambers over the machines are connected with an exhaust system which removes a sufficient quantity of the fume-laden air, to prevent an explosive concentration. At the present time no provision is made for solvent recovery, although the drying and ventilating system is so designed that an installation might be made with a minimum of expense and inconvenience. (*Chemical and Metallurgical Engineering*, vol. 28, no. 23, June 11, 1923, pp. 1017–1023, 17 figs., *d*)

The Fauser Synthetic Ammonia Process. In this process ammonia is synthetized and then oxidized to nitric acid to produce ammonium nitrate.

The method used in the new process does not materially differ in principle from those of Haber and Claude. The original features of the Fauser process are as follows:

1 The direct introduction of the water for the absorption of the ammonia by an induction pipe on the compressor, which lubricates the latter, is a considerable improvement, as the high-pressure pumps used in other processes may be dispensed with.

2 The condensing column, common to all methods and used to separate the lubricant introduced by the compressors, is used in this case to separate and absorb the ammonia.

3 A scientific system of heat recovery from the gases leaving the reaction chamber gives a marked economy in the fuel required to separate the ammonia from the aqueous solutions.

The outstanding feature of the new process is the way in which all waste is collected and utilized; the expensive liquid-air plant for obtaining the nitrogen gas required in the ammonia synthesis is eliminated, and the nitrogen used is obtained entirely from the residual gas left in the process of oxidizing the ammonia by air. The process as a whole forms an apparently perfect closed chain in which the electric power supplied converts the raw materials, air and water, into nitric acid or nitrates without any useless by-products.

The working pressure is slightly higher than in the Haber process (300 atmos. instead of 200), which appears to allow the liquefaction of the ammonia in the anhydrous state without difficulty. The uncondensed portion is absorbed in water under pressure, and afterward obtained by means of an ingenious system of recovery and stored in a gasholder. The layout of the plant also contains other interesting features making for economy both in the operations with liquid ammonia and with the nitric acid. (*The Chemical Age*, vol. 9, no. 213, July 14, 1923, pp. 28–30, 3 figs., *d*)

The Use of Oxygen or Oxygenated Air in Metallurgical and Allied Processes, F. W. Davis. In view of the many recent developments in oxygen manufacture, and considering the increasing cost and decreasing quality of our raw materials, the Bureau of Mines, Department of the Interior, appointed an Advisory Committee to study the problem of the application of oxygen or oxygenated air to metallurgical and allied processes. M. H. Roberts, vice president of the Franklin Railway Supply and consulting engineer of the Bureau of Mines, is chairman of the Committee.

This committee has made a thorough survey of the existing processes for the manufacture of 99 per cent oxygen. The conclusions reached by this survey are that the comparatively small demand for the product has prevented the installation of large units suitable for metallurgical processes, with corresponding economies, and by far the greater proportion of the present cost of oxygen represents the cost of transportation, storage, and service. Large oxygen-manufacturing plants can be built to serve metallurgical purposes directly, which will be capable of delivering oxygen at a cost not to exceed $3 per gross ton. In other words, the Committee finds that the oxygen industry is now able to make plants for supplying large quantities of oxygen to metallurgical industries at low cost.

The Committee has made studies of the possible application of oxygen to ferrous metallurgy in general, to the metallurgy of zinc, to the manufacture of fuel gas, and for some miscellaneous industrial uses. The findings of the Committee on these theoretical studies are of such a revolutionary character that the members feel the strong advisability of conducting experimental work to verify the truth thereof, as well as to make changes in furnace design and processes in order to take full advantage of the probable benefits to be gained.

The results of these studies indicate that not only will the use of oxygen decrease materially the cost of present metallurgical processes, but that it will make available for use large quantities of low-grade ore and fuel which is now considered worthless. (*Reports of Investigations, Bureau of Mines*, Serial no. 2502, July, 1923, *cp*)

Rolling Steel and Non-Ferrous Rings. Description of a process of making rolled rings for gear blanks and for bearing and spinning blanks as used by the Weldless Rolled Ring Co., Cleveland.

The process of making rolled rings includes two main steps. The first is forging a hollow blank smaller than the desired ring from round or square bar stock by the usual upsetting process on a 5-in. National flange machine. (Blanks for rings weighing from 20 to 75 lb. are forged under a drop hammer or power press.) After the blank is formed it is placed on the rolling machine and rolled out, the wall thickness being decreased and the diameter increased until a ring is formed of the desired size and shape.

Among the advantages claimed for the rolled rings are that they can be rolled close to size and that sections can be rolled that cannot be drop-forged. Thus the periphery and inside can be made in such forms as full channel sections or with grooves. (*The Iron Age*, vol. 112, no. 4, July 26, 1923, pp. 204–206, 7 figs., *d*)

TESTING AND MEASUREMENTS

Direct Determination of Dewpoints of Gasoline-Air Mixtures. A method of determining directly the dewpoints of gasoline-air mixtures in the proportions required for use in internal-combustion engines has been devised by W. A. Gruse and was presented to the division of petroleum chemistry of the American Chemical Society in a paper read before that society at New Haven, Conn., on April 5, 1923. It is based on a belief in the fundamental significance of the dewpoint of a gasoline-air mixture and consists of blowing a fuel mixture of known composition against an internally cooled metallic mirror and observing the temperature at which dew is formed.

A detailed description was given of the apparatus used in making the determination and the results obtained were compared with those secured by R. E. Wilson and D. P. Barnard, 4th, by their method of equilibrium mixtures in tests previously reported by them. The distillation curves of three commercial fuels bought in the open market at Pittsburgh were studied, their dewpoints were investigated, and the effects of adding 1 and 2 per cent of kerosene were observed with a view to determining the sensitiveness of the dewpoint in the presence of small amounts of heavy ends. Increases of from 4 to 6 deg. in the temperature at which dew formed were noted with practically all of these fuels.

A direct determination of the dewpoint of samples of the same fuels used and offered for test by Wilson and Barnard showed that their figures are approximately 20 deg. lower than those determined directly and that the change in the dewpoint corresponding to a change from a 12-to-1 to a 15-to-1 mixture is of the order of 7 or 8 deg. when measured directly, whereas Wilson and Barnard in their tests previously referred to found a uniform variation of approximately 4 or 5 deg. for a number of different fuels.

A comparison of the figures for a second group of fuels shows that the direct determination gives dewpoints that are higher in all cases than those arrived at by the equilibrium mixture. (*a*) The apparatus can be constructed in an ordinary laboratory and machine shop; (*b*) with a little practice the dewpoints can be read with fair accuracy and reproducibility; (*c*) it is believed to be sufficiently direct to be free from large errors; and (*d*) it applies to volatile fuels of any nature. It is offered tentatively as suitable for the direct determination of the "effective" volatility of motor fuel with the idea that it may be useful in studying specifications and blending operations and for the control of other methods of evaluation. (*The Journal of the Society of Automotive Engineers*, vol. 13, no. 2, August, 1923, p. 170, *ep*)

An Experimental Sensitive Balance. A balance devised by Hans Peterson is said to be capable of weighing to a sensitiveness of $^1/_{600,000,000}$th part of a grain. The beam of the balance is a small piece of quartz measuring less than 2 in. in length and weighing about a grain only. What would correspond to the pans in an ordinary pair of delicate scales are suspended from quartz threads a thousandth of a millimeter (one twenty-five-thousandth of an inch) in diameter.

The actual weighing is done by measuring the vibrations of the balance by means of a spot of light thrown upon a scale, which shows the actual movement of the balance enormously magnified.

Such refined weighing has to be done in a vacuum, and the instrument is mounted in a container from which the air can be exhausted before the actual work commences.

The balance itself weighs about 3 grains and is sensitive to the ten-millionth part of a milligram. (*American Journal of Pharmacy*, abstracted through *Merck's Report*, vol. 32, July, 1923, p. 96, *d*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general, *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Test Code for Locomotives

Preliminary Draft of Code No. 15 in the Series of Nineteen Being Formulated by the A.S.M.E. Committee on Power Test Codes

THE revision of the A.S.M.E. Power Test Codes of 1915 which was begun by the present Committee is now progressing rapidly. Below is reproduced the Test Code for Locomotives. The Individual Committee which developed this Code is headed by Prof. J. M. Snodgrass as Chairman and consists of Messrs. G. M. Basford, W. F. Kiesel, Jr., G. E. Rhoads, E. C. Schmidt, M. Toltz and C. D. Young.

The Committee and the Society will welcome suggestions for corrections to and modifications of this draft of its Code from those who are especially interested in the testing of locomotives. These comments should be addressed to the Chairman of the Committee, in care of The American Society of Mechanical Engineers, 29 West 39th Street, New York, N. Y.

Introduction

1 Locomotive tests are of two leading kinds, laboratory tests and road tests. The former are made in a locomotive laboratory under conditions quite similar to those of a stationary power plant in which the power is absorbed by a brake. The latter are made under conditions of service on the road, the locomotive hauling a train of cars. The rules for conducting tests of steam locomotives are therefore divided into two parts: a code for laboratory tests and a code for road tests.

2 The locomotive being a complete steam plant in itself, embracing boiler, engine, and certain auxiliaries, a locomotive test will in general be comparable with the test of a stationary plant embracing somewhat similar equipment. Where locomotive tests include detailed tests of auxiliary equipment, those portions of the A.S.M.E. test codes applicable to the particular auxiliary apparatus under test should be employed in so far as may be practicable in testing such auxiliary apparatus.

3 Where locomotive tests are made with some object in view which is different from the objects specifically covered by these codes, it is expected that the codes presented may constitute the basis for determining methods to be adopted, the data to be taken, et cetera. The codes are prepared for the test of a two-cylinder simple locomotive using superheated steam. When the locomotive tested is of a different kind from that for which the code is prepared, modifications may be required in the test procedure or in the reporting of the data and results. Where such modification of the code is necessary, it should be made with the view to reporting results which may be of the greatest possible value for comparative purposes with other test results reported under the code or under some slight modification thereof. In order that locomotive test data and test results may have the greatest possible value, particularly for comparison with more or less similar test data and results, it is desirable that the data taken be fairly complete as to the items indicated in the code here submitted, and that in the making of tests for special objects or with special locomotives the methods indicated in the codes as desirable be adopted in so far as conditions will permit. Where a fuel is used other than coal, for which the code is specifically prepared, modifications of the code may become necessary and should be governed by the same considerations concerning completeness and uniformity of data, and the desirability of reporting results that may be valuable for purpose of comparison.

Test Code for Laboratory Tests

Objects of Test

4 The object of a laboratory test as covered by this code is the determination of the coal and steam consumption per unit of power when the locomotive is operated under fixed conditions.

5 If the object of the test differs from that for which the code is specifically prepared the particular object should be determined and recorded in accordance with the suggestions of Pars. 1, 2, and 3 of the General Instructions, and the entire conduct of the test should be in accord with the object in view.

Measurements

6 The principal determinations which must be made in a test of a locomotive are:

(a) The engine and driving-wheel dimensions for horsepower calculations
(b) The leading boiler dimensions, such as grate surface, heating surface, and boiler volume, which enter into calculations involving coal and water consumption
(c) The operating conditions, such as throttle and reverse-lever positions, which define test conditions
(d) The speed
(e) The indicator diagrams for the determination of horsepower and engine conditions
(f) The temperature of laboratory, feedwater, superheated steam, in firebox, and in front end
(g) The barometric pressure
(h) The relative humidity of the atmosphere
(i) The boiler pressure
(j) The draft in ashpan, firebox, and front end
(k) The quality of the steam in the dome
(l) The weight of the feedwater and the weight of water and steam lost or used through leaks, auxiliary apparatus, etc.
(m) The weight of the coal fired
(n) The weight of the ash
(o) The weight of the cinders
(p) The chemical analysis and calorific determinations of the coal, ash, and cinders
(q) The composition of the front-end gases
(r) The blackness of the smoke
(s) The drawbar pull
(t) The dimensions and determinations that may be required in connection with such auxiliary apparatus as may constitute a part of the locomotive undergoing test.

Instruments and Apparatus

7 For laboratory tests it is assumed that a testing plant is available where the driving wheels can be mounted upon the supporting wheels of a friction-brake apparatus for suitably disposing of the power. The essential parts of the test plant which must be considered as necessary apparatus are:

(a) The mounting or revolving wheels upon which the drivers run while the locomotive is in operation
(b) The brake apparatus by which the work of the locomotive is absorbed and dissipated
(c) The dynamometer for the determination of the work done or the power developed.

A fourth piece of apparatus which, on account of its size, in order that it function properly, must generally be considered as a portion of a testing plant, is

(d) The cinder separator and collector.

8 Other apparatus and instruments required for a laboratory test are:

(e) Water-weighing apparatus
(f) Weighing apparatus for coal, ash, and cinders
(g) Graduated scale attached to the water glass
(h) Pressure gages, draft gages, thermometers, and pyrometers
(i) Barometer and hygrometer
(j) Speed-measuring apparatus
(k) Steam-engine indicators with indicator rigging or reducing motion
(l) Steam-sampling apparatus and steam calorimeter
(m) Gas-sampling and gas-analysis apparatus
(n) Coal-, ash-, and cinder-sampling apparatus
(o) Fuel calorimeter
(p) Smoke charts or other apparatus for the purpose of making smoke-density determinations.

In addition to the above it is necessary or desirable to have planimeters, micrometers, scales, calculating instruments, etc.

9 The laboratory test described in the Locomotive Code cannot readily be made unless a testing laboratory is available where the locomotive may be sent, and where this work may be carried on. Such a laboratory is too expensive to be constructed for the purpose of ascertaining the performance of an individual locomotive. How to arrange and install a laboratory testing plant seems therefore a matter for independent consideration.

10 At the present time the following universities have loco-

motive-testing laboratories: Purdue University, Lafayette, Ind.; University of Illinois, Urbana, Ill.; and Iowa State University, Ames, Iowa. Under certain arrangements locomotives may be sent to these laboratories for test purposes. Information concerning the design and operation of these laboratories has been published in reports concerning them and their work. The Pennsylvania Railroad Company maintains and operates a locomotive-testing laboratory at Altoona, Pa.

11 In 1904 the Pennsylvania Railroad Company carried on an elaborate series of locomotive-laboratory tests at the Louisiana Purchase Exposition, St. Louis, Mo. A description of the plant there installed, and of the tests made upon it, may be found in a volume published in 1905 by that company entitled, Locomotive Tests and Exhibits. This plant and the tests referred to were planned under counsel of an advisory board, three of whom were members of The American Society of Mechanical Engineers.

12 Directions regarding the use, the calibration, and the accuracy of the instruments mentioned in this section are given in Pars. ——— and ——— of the code on Instruments and Apparatus.

Preparations

13 Pars. 1 to 15, inclusive, of the General Instructions should be read and carefully studied.

13a Dimensions. General directions concerning dimensions are given in Pars. 4. 5, and 6 of the General Instructions, and Table 1 presents a form for recording the usual dimensions to be taken. In general the dimensions recorded should be determined by actual measurements of the locomotive undergoing test. The cylinder clearance may be determined approximately from working drawings of the locomotive. When this is done the dimensions used should be checked by actual measurements. When practicable the clearance should be determined by the water-measurement method. The water-measurement method of determining clearance is described in Par. 50 of the Rules for Conducting Tests of Reciprocating Steam Engines.

The dimensions of certain portions of the locomotive should be recorded, usually by reference to drawings or prints that may become a part of the recorded data. Such records, though varying somewhat with the nature and purpose of the test and the equipment tested, are indicated by and in general should include the following:

I The front-end-arrangement dimensions
II The location of the throttle valve and the actual lift of throttle valve in relation to throttle-lever position
III The reverse-lever arrangement and quadrant marking
IV The connection between the boiler and the gage glass which is used in determining height of water in the boiler.

13b Leakage. In general all leakage of water, steam, or air should be eliminated or reduced to a minimum. Where leakage is considered unavoidable or permitted for other reasons, its amount or effect should be determined with the greatest exactness possible. The principal ways in which serious loss or error through leakage may occur are:

I Blows past the piston and valve packings
II Leaky flues, leaks at mud ring or at boiler seams
III Leaks into the front end from superheater or other steam-pipe joints
IV Leaking throttle
V Air leaks into the front end.

Somewhat elaborate methods of determing leakage have been described in certain of the test codes such as those relating to Complete Steam Power Plants and Steam Engines which may be adapted to a greater or less extent in connection with the determination of leakage during locomotive tests. When the leakage may be considerable during a locomotive test and extreme accuracy is aimed at, the methods of determining leakage described in the various codes which are concerned with apparatus similar to that of the steam locomotive should be studied and made use of, in so far as may be practicable. For the most part leakage determinations in connections with locomotive tests can only be considered as somewhat roughly approximate and, where test conditions do not require otherwise, the effort should be made to eliminate leakage rather than to measure it accurately.

13c Physical Conditions. Attention to wear or variations from what are considered usual conditions as to dimensions should be given, particularly in regard to such items as the following:

I Preferably all driving wheels should be the same diameter and should be of standard contour. The exact method of taping the tires should be recorded
II Each pair of driving wheels should be checked to see that they are correctly quartered for the crankpin
III The frames should be tested to see that they line with the cylinders
IV The stack and draft pipe should be lined to determine that they are properly erected with reference to the exhaust nozzle
V Grates should be examined with regard to wear or broken parts.

13d Service. Records should be made concerning the previous performance of the locomotive, particularly of unusual service to which it may have been subjected or unusual attention which it may have received. The following indicate items for consideration:

I Miles run and nature of service since built or since last shopping for general repairs
II Nature of recent light repairs
III Methods of lubrication and kinds of lubricant used
IV Condition of the tubes and boiler as a whole regarding scale and sediment
V Information concerning the kind of water used during the tests and immediately prior thereto.
VI Valve gears should be checked that their performance may be known and compared with that of the standard for the locomotive.

13e Installation of the Testing Appliances Install and calibrate the testing appliances in accordance with Pars. 9 to 12 of the General Instructions and in accordance with the Main Code section on Instruments and Apparatus. The location of apparatus and instruments and their use in locomotive testing should in general be the same as in similar tests of stationary apparatus unless there is a good reason, on account of lack of space or other considerations, for variations from the usual practice. Reference may be made to the boiler and engine codes or to such other A.S.M.E. codes as are concerned with apparatus similar to that tested during a locomotive test. A suitable signal arrangement should be installed so that observations may be properly timed and that, where desirable, simultaneous observations may be made.

Two water-weighing tanks of about 1500 lb. capacity each, placed upon platform scales of about 2500 lb. capacity, and one receiving tank of about 250 cu. ft. capacity make up a convenient-sized arrangement for weighing feedwater The receiving tank should preferably be at a level corresponding with the usual locomotive tank so that the head of water at the feed pump or injector will be that found in practice. The overflow from the injector should be caught in a small tank (30 to 50 cu. ft.) and returned to the receiving tank so that there will be no need to make correction for loss of feedwater at this point. Platform scales with one tare beam for weighing coal should be of about 2500 lb. capa ity, and the coal can be conveniently handled in wagons holding 1000 lb. each.

Whenever possible, it is best to arrange such gages as are required on supports apart from the locomotive and to use small copper or lead tubing in making connections. The pressure gage belonging to the locomotive usually has a scale of graduation which is too coarse for use in tests and its location in the cab is not satisfactory on account of inaccessibility and vibration. This gage should remain in place and new connection should be made in the pipe leading to it, and a gage having suitable range and graduated to single pounds should be connected and mounted on a firm support near the cab.

The gage glass which is used in determining the height of water in the boiler should be so connected as to give correct indications of water level. This can usually be assured by making the top gage-glass connection through the roof sheet somewhat forward of the back head sheet.

In the locomotive smokebox the draft pipes should extend to the vertical center line, one in front of and one back of the diaphragm. The draft pipes may be 1/4-in. iron pipe and should have a plain open end facing across the flow of gases so as not to become stopped with cinders. The draft connection to the firebox should be about midway of the length of the grates and about 24 in. above them. This draft pipe can usually be inserted through a staybolt. The draft pipe in the ashpan should have its open end at a point near the center of the grates.

Figs. 1 and 2 present diagrams showing the approximate location of a number of the instruments used during locomotive tests. Judgment must always be exercised in the location of instruments in order that data may be secured which are truly representative of the conditions which are to be determined.

The locomotive speed should be measured by a revolution counter applied, preferably, to the main drivers. A speed indicator, as of the electromagnetic type, with the indicating dial in view of the speed-control operator, should also be used.

The indicator driving rig should be rigid and of a form which will not introduce errors in the motion of the indicator drum. Frequent inspection of the parts subject to wear should be made and lost motion should be eliminated.

The steam-sampling apparatus should, ordinarily, be located in the steam dome in such a manner as to obtain as representative a sample as may be possible. A throttling calorimeter is generally the most satisfactory type of instrument to use. In case the amount of moisture in the steam is so great that it cannot be measured with a throttling calorimeter, a separating calorimeter should also be used.

The sample of gases for the flue- or smokebox-gas analysis should be drawn from the region near the center of the main body of escaping gases, using a sampling device designed to collect a representative sample of the gases. Such a sampling device may be made from 1/2-in. iron pipe and may be introduced horizontally through the smokebox front, preferably about the center of the gas passage between the bottom of the smokebox and the table plate. The entrance end of the pipe should be bent to form a part extending across the current of gases and this part should contain perforations opening toward the current of the gases, the collection area of the perforations being less than the area of the pipe.

13f Fuel. The coal used should, in general, be of some kind that is regarded as a standard for locomotives of the same general kind and service as the locomotive undergong test, or standard for the locality where the test is made. The fireman should have sufficient familiarity with the coal used, or be otherwise able to handle it satisfactorily. Where tests are made with a special object in view it may be necessary to select the fuel in accordance with that object.

13g Preparatory Tests and Determinations. Certain preliminary or auxiliary tests are in general necessary or desirable:

I A calibration of the boiler, which in particular will show the

weight of water contained in that part of the boiler corresponding to the gage glass, should be made previous to the test proper.

II The rate of discharge of steam through the safety valves should be determined

III Tests of or determinations concerning auxiliary equipment should be made to determine the conditions under which they are operating and the amount of steam and coal required for their operation.

13h Sampling Coal. Previous to or during the progress of the trial, the coal should be sampled in the manner provided for in Pars. ——— of the code section on Fuels. Too much emphasis can hardly be placed on the importance of proper coal sampling.

13i Chemical Analyses and Calorific Determinations. Chemical analyses and calorific determinations of the coal sample are to be made in accordance with Pars. ——— of the Test Code on Fuels, as are also the chemical analyses of the front-end gases.

13j Ash and Cinders. The ash withdrawn from the ashpan, or elsewhere collected, and the cinders from the front end or cinder collector shall be sampled as nearly in accordance with the directions for sampling coal as circumstances will permit. For the samples of the ash and cinders, calorific determinations shall be made in the same manner as similar determinations for coal. Chemical analyses, at least to the extent of determining the combustible content of the ash and cinders, are to be made in accordance with the methods governing the coal analyses.

Operating Conditions

14 Determine what the operating conditions are to be and note the information and directions given in Par. 10 of the General Instructions. In general, the predetermined operating conditions, the effect or relation of which are to be studied, or such operating conditions as appreciably affect the test, should be maintained as nearly uniform during the test as the limitations of the work will permit. There should be, in general, uniformity in such matters as steam pressure, times of firing, quantity of fuel supplied at each firing, speed, rate of supplying feedwater, cut-off, and in the load applied. It is particularly important that the firing should be in the hands of skilled firemen and that, in so far as may be possible, one fireman be used throughout any one test or series of tests which are to be compared.

15 Unless special conditions require otherwise, the locomotive undergoing test should be practically free from scale, and during a test or series of tests it should also be free from unusual accumulations of sediment. During a long series of tests such boiler washing and other cleaning of the heating surfaces must be arranged for as, in the judgment of the test directors, will give most representative and reliable results. Records should be made concerning such washings or cleaning operations as are carried on. The fire side of the heating surface should in like manner be practically clean before starting a test and should be maintained in uniformly good condition in this respect throughout a series of tests. Whenever there is a liability of even moderate cinder accumulations upon the back tube sheet or in the superheater flues, or the accumulation of loose ash and cinders in the flues and tubes, such parts should be cleaned prior to each test. In general, tubes and flues should be inspected after each one or two tests, or daily, and blown out as may be necessary and as test conditions permit. Where more thoroughgoing cleaning operations may be required, as in a long series of tests, such operations should be conducted at comparatively short intervals of time and record kept thereof.

Starting and Stopping

16 Consult Pars. 16, 17 and 18 of the General Instructions. Preferably, fires should be built up from a clean grate for each test. Where this is impracticable, the fire having been thoroughly cleaned, and banked when necessary, the bank should be broken up and fresh fuel supplied. The locomotive should be started and run, at the speed of the test, a sufficient length of time to build a level fire. All conditions of fire and speed having become uniform, the locomotive should be operated for at least ten minutes under the predetermined operating conditions before the test should begin. On signal observe the fire conditions, steam pressure, water level in boiler, and the time, and record the latter as the starting time of the test. The ashpan should be clean at the starting signal. In closing a test, simultaneous observations should be made upon steam pressure, water level, and fire conditions, and the time recorded as the close of the test. When the test is completed, the ashpan should be cleaned, and the ashes and cinders accumulated during the test should be collected as soon as possible.

17 In general, it is extremely desirable that such firebed conditions may be maintained as will permit substantially the same amount of combustible upon the grate at the start and at the close of the test. It is also, in general, desirable to close a test with the same or practically the same steam pressure and water level as obtained at the start of the test.

Duration

18 The duration of a laboratory test of a locomotive will depend to some extent upon the character of the fuel used, the rate of combustion, and the working limitations of the moving parts. The test should preferably be continued until at least 25 lb. equivalent evaporation of water per square foot of water-heating surface has been obtained. If however, the coal and water consumption are uniform, tests of three hours will be sufficiently long in any case.

Records

19 Consult Pars. 20 to 30 of the General Instructions for directions concerning records. The data should be taken in such manner that the test may be subdivided into a number of comparatively short periods and that the leading data thus obtained for any one or more of such periods may show the degree of uniformity obtained. Coal and water observations in particular should be taken in such manner as to facilitate subdivision of this kind. Observations in general should be taken every ten minutes and when it is essential that a number of observations be taken simultaneously, a sufficient number of observers must be available.

Calculation of Results

20 Pars. 31 to 35 of the General Instructions present information with regard to working up data. The present section, Calculation of Results, gives in detail methods for calculating the results listed in Table 1 excepting those items whose determination is more or less self-evident. For additional directions relative to methods of calculating boiler and engine results, reference may be made to Pars. —— and —— of the Boiler Code and Pars. —— and —— of the Engine Code. For methods of calculating results pertaining to auxiliary apparatus, reference should be made to the individual codes relating to such apparatus.

21 The events of the stroke and the corresponding pressures should be determined for each indicator diagram by inspection and measurement. The values recorded should be averages of the determinations made from individual diagrams. Indicated-horsepower calculations should be made for each indicator diagram. Pars. 13 and 13*a* of the code for reciprocating steam engines outline the method to be employed.

22 The "heat distribution" or "heat balance," Item 41 of Table 1, should be calculated in accordance with the instructions given in the Boiler Code, Pars. ———, under Computations for Test with Solid Fuels.

Method of Calculating Individual Items

Item 22 Revolutions of Driving Wheels per Minute:

$$\frac{\text{Item } 22(a)}{\text{Item } 18 \times 60}$$

Item 22(*b*) Speed Equivalent of R. P. M., Miles per Hour:

$$\frac{\text{Item } 22 \times \text{Item } 3(c) \times 60}{5280}$$

Item 22(*d*) Piston Speed, Feet per Minute:

$$\frac{[\text{Item } 13(a) + \text{Item } 14(a)] \times \text{Item } 22}{12}$$

Item 23 Temperature of Feedwater:

This is the temperature of the feedwater taken before heat is added to it from the locomotive in any way. In the case of locomotives equipped with feedwater heaters, particularly when exhaust steam or condensate is returned to the feedwater supply, Item 23 must be so determined as to give the locomotive credit for all heat transferred to the feedwater by this exhaust steam or condensate added.

Item 24(*e*) Relative Humidity, Moisture per Pound of Dry Air, Pounds:

The relative humidity should be determined by the use of apparatus as described in Pars. ——— of the code on Instruments and Apparatus. The Locomotive Code assumes that the relative humidity will be calculated from the temperature data taken from wet- and dry-bulb thermometers.

Item 26(*c*) Barometric Pressure, Pounds per Square Inch:
The barometric pressure should be obtained from a suitable barometer as described in Pars. ——— of the code on Instruments and Apparatus. No correction need ordinarily be made to the observed values.

Item 30 Smoke, Percentage as Observed:
Smoke-density determinations should ordinarily be made through the use of the Ringlemann smoke charts as described in Pars. —— to —— of the code on Instruments and Apparatus.

Item 32(*a*) Dry Coal Fired, Total, Pounds:

$$\text{Item 32} \times \frac{100 - \text{Item 28}(g)}{100}$$

Item 34 Quality of Steam in Dome, Per Cent:
Quality of steam in the dome when determined by means of a throttling calorimeter should be calculated by the formula:

$$x_0 = \frac{H_c + 0.47 \times (t_r - t_c) - h_0}{L_0}$$

where

x_0 = quality of steam
t_r = observed temperature in calorimeter
t_c = temperature of saturated steam at pressure in calorimeter
h_0 = heat of liquid due to boiler pressure
H_c = total heat of dry steam at calorimeter pressure
L_0 = latent heat of dry steam due to boiler pressure.

Item 34 should be an average of the individual determinations of x_0.

Item 34(*a*) Superheat in Branch Pipe, Degrees:
Item 24 — t_b

where

t_b = temperature of saturated steam at branch-pipe pressure.

Item 35 Water Evaporated, Total, Pounds:
Item 35(*a*) + Item 35(*c*) — Item 35(*d*)

Item 35(*a*) Water Delivered to Boiler:
In the case of locomotives not equipped with feedwater heaters or those equipped with heaters which do not return any exhaust steam or condensate to the feedwater supply, the determination of the total water delivered to the boiler is generally readily arranged for. In the case of locomotives equipped with open feedwater heaters or other heaters in the operation of which exhaust steam or condensate is returned to the feedwater supply, special provision must be made to determine the total amount of water delivered to the boiler. This is to be done in such a way that both the total water delivered to the boiler and the amount of the exhaust steam or condensate additions are determined. Furthermore, in the case of locomotives in which exhaust steam or condensate is returned to the feedwater supply, all results involving water or steam supply must be so calculated that, first, items of boiler performance will credit the boiler with all heat transferred to the water and steam; second, items of engine performance will charge the engines with all of the steam (or heat) delivered to them; and third, items of general locomotive performance will show the proper relations between locomotive output and the amounts of coal and water delivered to the locomotive. The type and arrangement of the feedwater heater will, to a large extent, determine the original observations which must be made, the methods which must be employed in making them, and the manner in which subsequent calculations must be modified in order to properly include the performance of the feedwater heater.

In general, in testing locomotives with feedwater heaters, in addition to the determination of the amount and temperature of the inlet water, there should be determined the temperature of the outlet water and, in the case of open heaters, the temperature and pressure of the exhaust steam going to the feedwater heater. Wherever the feedwater supply is heated through the return of exhaust steam or condensate, sufficient observations must be made concerning the amounts and temperatures of the water affected to make possible the calculations of boiler, engine, and overall performance already mentioned.

In case that a more complete test of the feedwater heater is desired than that involved in determining the performance and efficiency of the locomotive as outlined in this code, reference should be made to the Test Code for Feedwater Heaters.

Item 35(*b*) Weight of Water in Boiler at Start of Test Minus. Weight of Water in Boiler at Close of Test, Pounds:
This item may be obtained from the boiler gage-glass calibration. The total weight of the water in the boiler should be determined from a calibration which may be made by filling the boiler with weighed water or may be made approximately through calculations based upon the boiler dimensions.

Item 35(*c*) Boiler Corrections for Change of Water Level and Change of Pressure in the Boiler from Start to Close of Test may be calculated by the formula:

$$\frac{w_i\,(h_a + xL - h_i) - w_f\,(h_a + xL - h_f)}{h_a + xL - h}$$

where

w_i = initial weight of water in the boiler, pounds
w_f = final weight of water in the boiler, pounds
h_a = heat of liquid due to average boiler pressure
x = quality of steam, average
L = latent heat of dry steam due to average boiler pressure
h_i = heat content of liquid at start of test
h_f = heat content of liquid at close of test
h = heat content of liquid due to average feedwater temperature.

In case that the test can be closed with approximately the same water level and the same boiler pressure as obtained at the the start of the test, the boiler correction becomes small and may ordinarily be disregarded.

Item 35(*d*) Water Losses, Pounds:
The hot water, as measured or estimated, which is lost through leaks or otherwise.

In case that this loss is considerable it may seem desirable to substitute, for Item 35(*d*), as just defined, a corrected value which will take account of the heat transferred to the lost water. This "corrected hot-water losses" may be calculated as follows:

$$\text{Water losses (lb.)} \times \frac{xL}{h_a + xL - h}$$

Ordinarily no attempt need be made to apply this correction.

Item 35(*e*) Moist Steam Lost or Used Other Than That Going to the Main-Engine Cylinders, and—

Item 35(*f*) Superheated Steam Lost or Used Other Than That Going to the Main-Engine Cylinders:
Items 35(*e*) and 35(*f*) should be measured or estimated as circumstances and available data will permit. Preliminary runs or determinations may be useful in the determination of these items. In the final report Items 35(*e*) and 35(*f*) should be shown subdivided into such separate items as may seem desirable and the data taken will permit, in order to show the total and hourly quantities of steam used by the different auxiliaries.

Item 36 Steam to Superheater per Hour, Pounds:

$$\frac{\text{Item 35}(a) + \text{Item 35}(b) - \text{Item 35}(d) - \text{Item 35}(e)}{\text{Item 18}}$$

Item 36(*a*) Moist Steam per Hour, Pounds:

$$\frac{\text{Item 35}}{\text{Item 18}}$$

Item 36(*b*) Heat Transfer Across Water-Heating Surface per Hour, Thousands of B.t.u.:

$$\frac{\text{Item 36}(a) \times (h_a + xL - h)}{1000}$$

$h_a + xL - h$ = the heat added to each pound of water evaporated by the boiler exclusive of the superheater.

Item 36(*c*) Heat Transfer Across Superheating Surface per Hour, Thousands of B.t.u.:

$$\frac{\text{Item 36} \times (H_s - h_a - xL)}{1000}$$

$H_s - h_a - xL$ = the heat added to each pound of steam passing through the superheater.
H_s = total heat of steam at branch pipe pressure.

Item 37 Total Heat Transfer per Hour, Thousands of B.t.u.:
Item 36(*b*) + Item 36(*c*)

Item 37(*a*) Heat Transfer per Hour per Sq. Ft. of Heating Surface, Thousands of B.t.u.:

$$\frac{\text{Item 37}}{\text{Item 11}}$$

Item 39 Superheated Steam per Hour, Pounds:

$$\frac{\text{Item 37} \times 1000}{H_s - h}$$

Item 40(*b*) Superheated Steam per Hour per Sq. Ft. of Heating Surface:

$$\frac{\text{Item 39}}{\text{Item 11}}$$

Item 41 Efficiency of Boiler, Per Cent:

$$\frac{\text{Item 37} \times 1000}{\text{Item 33} \times \text{Item 28}} \times 100$$

Item 42 Steam Delivered to the Engines per Hour, Pounds:
Item 36 — Item 35(*f*)

Item 42(*a*) Coal-as-Fired Equivalent of the Water and Steam Losses, Pounds per Hour:

$$\frac{\text{Item 39} - \text{Item 42}}{\text{Item 40}}$$

Item 42(*b*) Dry-Coal Equivalent of the Water and Steam Losses, Pounds per Hour:

$$\frac{\text{Item 39} - \text{Item 42}}{\text{Item 40}(a)}$$

Item 45 Coal as Fired per I.Hp. per Hour, Pounds:

$$\frac{\text{Item 33} - \text{Item 42}(a)}{\text{Item 44}}$$

Item 45(*a*) Dry Coal per I.Hp. per Hour, Pounds:

$$\frac{\text{Item 33}(c) - \text{Item 42}(b)}{\text{Item 44}}$$

Item 46 Steam per I.Hp. per Hour, Pounds:

$$\frac{\text{Item 42}}{\text{Item 44}}$$

Item 46(*a*) B. T. U. of Coal Consumed per I. Hp. per Hour:

Item 45 × Item 28

Item 47 Drawbar Horsepower:

$$\frac{\text{Item 3(c)} \times \text{Item 22} \times \text{Item 47(a)}}{33{,}000}$$

Item 48 Coal as Fired per Drawbar Horsepower per Hour, Pounds:

$$\frac{\text{Item 33}}{\text{Item 47}}$$

Item 48(*a*) Dry Coal per Drawbar Horsepower per Hour, Pounds:

$$\frac{\text{Item 33(c)}}{\text{Item 47}}$$

Item 49 Steam per D.Hp. per Hour, Pounds:

$$\frac{\text{Item 36a}}{\text{Item 47}}$$

Item 49(*a*) B. T. U. of Coal Consumed per D.Hp. per Hour:

Item 48 × Item 28

Item 50 Friction Horsepower:

Item 44 — Item 47

Item 50(*a*) Locomotive Friction Expressed as Drawbar Pull, Pounds:

$$\frac{\text{Item 50} \times 33000}{\text{Item 3(c)} \times \text{Item 22}}$$

Item 51 Machine Efficiency of the Locomotive, Per Cent:

$$\frac{\text{Item 47}}{\text{Item 44}} \times 100$$

Item 52 Efficiency of the Locomotive, Per Cent:

$$\frac{2545}{\text{Item 49(a)}} \times 100$$

Final Report

23 The data and results should be reported in accordance with the form, Table 1, given herewith. Pars. 36 and 37 of the General Instructions present information regarding the form and substance of a final report. Under Item 10 of Table 1 the various pieces of auxiliary apparatus which are used should, if special, be named and either here or elsewhere in the final report such dimensions and descriptions of the apparatus should be given as will be of assistance in making clear test conditions and test results.

24 It is desirable that the test number and the test designation be so given that each test or run may be readily distinguished from any other test or run. This end would be accomplished for a given laboratory if that laboratory would issue test numbers consecutively. Where a number of runs or trials constitute a series of tests it is also desirable to so select test numbers that different tests series may be somewhat readily distinguished one from the other. The test designation should give in brief form certain important test conditions which will be useful for reference purposes. Uniformity in the form of the test designation as between different series of test and as between different laboratories is desirable. The following is recommended as a suitable form for the test designation: *** — ** — * where the digits *** express speed in revolutions per minute, the digits ** express cut-off in per cent, and the letter F or P, (the final digit, *) indicates a full or a partially opened throttle.

TABLE 1 DATA AND RESULTS OF LABORATORY TEST OF A LOCOMOTIVE

A S.M.E. Code of 19—

(1) Test number:
- (*a*) Test designation..........

(2) Test of:
- (*a*) Test made at..........
- (*b*) To determine..........
- (*c*) Test conducted by..........
- (*d*) Locomotive, type and class..........
- (*e*) Locomotive, number of..........

Dimensions and Proportions

(3) Rated tractive force..........lb.
- (*a*) Driving wheels, number of pairs..........
- (*b*) Driving wheels, nominal diameter..........in.
- (*c*) Driving wheels, average circumference, measured..........ft.
- (*d*) Driving wheels, average diameter, measured..........in.
- (*e*) Engine truck wheels, number of pairs..........
- (*f*) Engine truck wheels, diameter..........in.
- (*g*) Trailing wheels, number of pairs..........
- (*h*) Trailing wheels, diameter..........in.

(4) Wheelbase, driving..........in.
- (*a*) Wheelbase, total..........ft.
- (*b*) Gage of wheels..........in.

(5) Weight of locomotive, with water at second gage cock and average fire..........lb.
- (*a*) Weight on leading truck..........lb.
- (*b*) Weight on drivers..........lb.
- (*c*) Weight on trailing truck..........lb.
- (*d*) Weight of tender, loaded..........lb.
- (*e*) Capacity of tender, coal..........tons
- (*f*) Capacity of tender, water..........gal.

(6) Boiler, type..........
- (*a*) First ring, outside diameter..........in.
- (*b*) Tubes, number..........
- (*c*) Tubes, outside diameter..........in.
- (*d*) Tubes, thickness..........in.
- (*e*) Superheater flues, number..........
- (*f*) Superheater flues, outside diameter..........in.
- (*g*) Superheater flues, thickness..........in.
- (*h*) Length between tube sheets..........in.
- (*i*) Fire area of tubes and flues..........sq. ft.
- (*j*) Arch tubes, number..........
- (*k*) Arch tubes, outside diameter..........in.
- (*l*) Arch tubes, thickness..........in.
- (*m*) Arch tubes, length..........in.
- (*n*) Firebox, length..........in.
- (*o*) Firebox, width..........in.
- (*p*) Firebox, depth..........in
- (*q*) Firebox, volume..........cu. ft.
- (*r*) Fire doors, number..........
- (*s*) Fire-door openings, area..........sq. ft.
- (*t*) Fire doors, hand or power operated..........
- (*u*) Water space in boiler below second gage cock..........cu. ft.
- (*v*) Steam space in boiler above second gage cock..........cu. ft.

(7) Grate area..........sq. ft.
- (*a*) Grate, width..........in.
- (*b*) Grate, length..........in.
- (*c*) Grate, style of..........

(8) Air inlets to firebox, total..........sq. ft.
- (*a*) Air inlets through grate..........sq. ft.
- (*b*) Air inlets above the fuel bed..........
- (*c*) Ratio of air inlets through grate to grate area..........per cent
- (*d*) Ratio of total air inlets to grate area..........per cent
- (*e*) Area of air inlets to ashpan..........sq. ft.
- (*f*) Ratio of ashpan air inlets to area of tube and flue opening..........per cent

(9) Superheater, type..........
- (*a*) Superheater elements, number..........
- (*b*) Superheater elements, length in flue..........in.
- (*c*) Superheater tubes, outside diameter..........in.
- (*d*) Superheater tubes, thickness..........in.

(10) Auxiliary apparatus:
- (*a*) Brick arch
- (*b*) Feedwater heater
- (*c*) Stoker
- (*d*) Reverse gear
- (*e*) Air compressor
- (*f*) Electric generator
- (*g*) Grate shaker
- (*h*) Injectors
- (*i*) Safety valves
- (*j*) Thermic siphons
- (*k*) Circulating plates
- (*l*) Booster engines

(11) Heating surface, total, based on inside of firebox, fire side of tubes, flues, arch tubes and superheater..........sq. ft.
- (*a*) Heating surface of the tubes and flues, fire side..........sq. ft.
- (*b*) Heating surface of the firebox, fire side..........sq. ft.
- (*c*) Heating surface of superheater, fire side..........sq. ft.
- (*d*) Heating surface of arch tubes, fire side..........sq. ft.

(12) Exhaust nozzle, type..........in.
- (*a*) Dimensions,..........in.
- (*b*) Area, net,..........sq. in.

(13) Cylinder diameter, right side..........in
- (*a*) Piston stroke, right side..........in.
- (*b*) Piston-rod diameter, right side..........in.
- (*c*) Tail-rod diameter, right side..........in.
- (*d*) Clearance, right side, head end..........per cent
- (*e*) Clearance, right side, crank end..........per cent

(14) Cylinder diameter, left side..........in.
- (*a*) Piston stroke, left side..........in.
- (*b*) Piston-rod diameter, left side..........in.
- (*c*) Tail-rod diameter, left side..........in.
- (*d*) Clearance, left side, head end..........per cent
- (*e*) Clearance, left side, crank end..........per cent

(15) Valves, type..........
- (*a*) Steam ports, area..........sq. in.
- (*b*) Valve travel, maximum..........in.

(c) Steam lap.......in.
(d) Exhaust lap.......in.
(e) Valve motion, type.......

(16) Ratio of heating surface to grate area:
(a) Ratio of fire area through tubes and flues to grate area......
(b) Ratio of firebox heating surface to grate area..........
(c) Ratio of tube and flue surface to firebox heating surface..
(d) Ratio of firebox volume to grate area..................

DATE, DURATION, ETC.

(17) Date.......
(18) Duration of test.......hr.
(19) Coal, kind and size:
(a) Method of firing,.......
(b) Firebed, approximate thickness.......in.
(20) Reverse lever position.......
(21) Throttle opening.......

SPEED

(22) Revolutions of driving wheels per min.......
(a) Revolutions of driving wheels, total.......
(b) Speed equivalent of r.p.m.......miles per hour
(c) Equivalent length of run.......miles
(d) Piston speed.......ft. per min.

BOILER PERFORMANCE

Average Pressures, Temperatures, Etc.:

(23) Temperature of feedwater.......deg. fahr.
(24) Temperature of steam in branch pipe.......deg. fahr.
(a) Temperature of steam in exhaust passage.......deg. fahr.
(b) Temperature of laboratory, dry-bulb.......deg. fahr.
(c) Temperature of laboratory, wet-bulb.......deg. fahr.
(d) Outdoor temperature.......deg. fahr.
(e) Humidity, moisture per pound of dry air.......lb.
(25) Temperature in smokebox.......deg. fahr.
(a) Temperature in firebox.......deg. fahr
(26) Boiler pressure, gage.......lb. per sq. in.
(a) Branch-pipe pressure.......lb. per sq. in.
(b) Exhaust-passage pressure.......lb. per sq. in.
(c) Barometric pressure.......lb. per sq. in.
(27) Draft in smokebox, front of diaphragm.......in. of water
(a) Draft in smokebox, back of diaphragm, below superheat damper.......in. of water
(b) Draft in firebox.......in. of water
(c) Draft in ashpan.......in. of water

Heating Value and Analysis of Coal, Ash and Cinders:

(28) Heating value per pound of coal as fired.......B.t.u.
(a) Heating value per lb. of dry coal.......B.t.u.
(b) Heating value per lb. of combustible.......B.t.u.
(c) Heating value per lb. of cinders.......B.t.u.
(d) Heating value per lb. of ash.......B.t.u.

Proximate Analysis of Coal as Fired:
(e) Fixed carbon.......per cent
(f) Volatile matter.......per cent
(g) Moisture.......per cent
(h) Ash.......per cent
(i) Sulphur, determined separately.......per cent

Ultimate Analysis of Coal as Fired:
(j) Carbon.......per cent
(k) Hydrogen.......per cent
(l) Nitrogen.......per cent
(m) Oxygen.......per cent

Analysis of Ash:
(n) Carbon.......per cent
(o) Earthy matter.......per cent
(p) Moisture.......per cent

Analysis of Cinders:
(q) Carbon.......per cent
(r) Earthy matter.......per cent
(s) Moisture.......per cent

Analysis of Dry Smokebox Gases, by Volume

(29) Carbon dioxide (CO_2).......per cent
(a) Oxygen (O_2).......per cent
(b) Carbon monoxide (CO).......per cent

Smoke:

(30) Percentage of smoke as observed.......per cent

Cinders and Ash:

(31) Total ash collected from ashpan.......lb.
(a) Ash collected, per cent of total dry coal fired.......
(b) Ash by analysis, total.......lb.
(c) Ash collected, per cent of ash by analysis.......
(d) Cinders collected in smokebox.......lb.
(e) Cinders discharged from stack.......lb.
(f) Cinders, total.......lb.
(g) Ratio of weights, total cinders to total dry coal fired......

Coal and Rate of Combustion:

(32) Coal fired, total.......lb.
(a) Dry coal fired, total.......lb.
(b) Combustible, by analysis, total.......lb.
(33) Coal as fired per hour.......lb.
(a) Coal as fired per hour per sq. ft. of grate surface.......lb.
(b) Coal as fired per hour per cu. ft. of firebox volume.......lb.
(c) Dry coal fired per hour.......lb.
(d) Dry coal fired per hour per sq. ft. of grate surface.......lb.

Quality of Steam:

(34) Quality of steam in dome.......per cent
(a) Superheat of steam in branch pipe.......deg. fahr.
(b) Superheat in exhaust steam.......deg. fahr.

Water and Steam:

(35) Water evaporated, total.......lb.
(a) Water delivered to boiler.......lb.
(b) Weight of water in boiler at start of test minus weight of water in boiler at close of test (plus or minus).......lb.
(c) Boiler correction.......lb.
(d) Water losses.......lb.
(e) Moist steam used at auxiliaries, calorimeter, safety valve, steam leaks, etc., total.......lb.
(f) Superheated steam used or lost before reaching the engine cylinders, total.......lb.

Evaporation:

(36) Steam to superheater per hour.......lb.
(a) Moist steam per hour.......lb.
(b) Heat transfer across water heating surface per hour (units of evaporation).......1000 B.t.u.
(c) Heat transfer across superheating surface per hour (units of evaporation).......1000 B.t.u.
(37) Total heat transfer per hour (units of evaporation)...1000 B.t.u.
(a) Heat transfer per hour per sq. ft. of heating surface (units of evaporation).......1000 B.t.u.
(38) Units of evaporation per pound of coal as fired......1000 B.t.u.
(a) Units of evaporation per pound of dry coal...1000 B.t.u.
(39) Superheated steam per hour.......lb.
(40) Superheated steam per lb. of coal as fired.......lb.
(a) Superheated steam per pound of dry coal.......lb.
(b) Superheated steam per hour per sq. ft. of heating surface.......lb.

Efficiency and Heat Distribution (per cent of heat units fired):

(41) Efficiency of boiler and furnace (heat absorbed by boiler)..per cent
(a) Loss of heat due to moisture in coal.......per cent
(b) Loss of heat due to moisture in air.......per cent
(c) Loss of heat due to hydrogen content of coal.......per cent
(d) Loss of heat due to heat in escaping gases.......per cent
(e) Loss of heat due to escaping combustible gases.......per cent
(f) Loss of heat due to cinders.......per cent
(g) Loss of heat due to ashpan losses.......per cent
(h) Loss of heat due to radiation and unaccounted for..per cent

ENGINE PERFORMANCE

Steam to Engines:

(42) Steam delivered to the engines per hour.......lb.
(a) Coal-as-fired equivalent of the water and steam losses per hour.......lb.
(b) Dry-coal equivalent of the water and steam losses per hour.......lb.

Events and Pressures from Indicator Diagrams, Averages:

(43) Mean effective pressure.......lb. per sq. in.
(a) Cut-off.......per cent of stroke
(b) Steam-chest pressure.......lb. per sq. in.
(c) Initial pressure.......lb. per sq. in.
(d) Pressure at cut-off.......lb. per sq. in.
(e) Least back pressure.......lb. per sq. in.

Indicated Horsepower:

(44) Indicated horsepower.......i.hp.
(a) Right side, head end.......i.hp.
(b) Right side, crank end.......i.hp.
(c) Left side, head end.......i.hp.
(d) Left side, crank end.......i.hp.
(45) Coal as fired per i.hp. per hour.......lb.
(a) Dry coal per i.hp. per hour.......lb.
(46) Steam per i.hp. per hour.......lb.
(a) B.t.u. of coal consumed per d.hp. per hour.......

GENERAL LOCOMOTIVE PERFORMANCE

Drawbar Horsepower:

(47) Drawbar horsepower.......d.hp.
(a) Average drawbar pull.......lb.
(48) Coal as fired per d.hp. per hour.......lb.
(a) Dry coal per d.hp. per hour.......lb.
(49) Steam per d.hp. per hour.......lb.
(a) B.t.u. of coal consumed per hour.......

Locomotive Friction:

(50) Friction horsepower..............................

(*a*) Locomotive friction expressed as pull at drawbar......lb.

Efficiency:

(51) Machine efficiency of the locomotive ....per cent

(52) Efficiency of the locomotive..........................per cent

Test Code for Road Test

Object of Test

25 The object of a road test, as covered by this code, is the determination of the coal and steam consumption of a locomotive per unit of power under the conditions of road service.

26 If the object of the test differs from that for which the code is specifically prepared, the particular object should be determined and recorded in accordance with the suggestions of Pars. 1, 2 and 3 of the General Instructions and the entire conduct of the test should be in accord with the object in view.

27 Locomotive road tests are inherently less accurate than laboratory tests. The precise measurement of coal and water is much more difficult on the road, as well as the determination of some of the other data. Under the usual conditions of road service there are bound to be wide fluctuations in speed, drawbar pull, and rate of firing, all fundamental factors in performance; and even under the most rigid control much of this variation will inevitably remain and exercise an important influence on the results. In a locomotive, cut-off and speed, for example, vitally affect the steam consumption, which varies widely with both; and boiler performance likewise varies greatly with the rate at which the boiler is driven. In short, in a road test we are dealing with a power plant operating under speeds and loads which frequently vary from zero to more than 100 per cent above the average.

28 If the purpose of the test, therefore, is such as to make necessary an accurate determination of the water rate or rate of evaporation, road tests will not give reliable results and the locomotive must be tested in a laboratory. There are other purposes for which road tests are inherently unsuited. Whatever their purpose, road tests are difficult to make, and unless they are thoroughly prepared for and conducted with great skill and care their results are likely to be misleading and frequently worse than useless.

Measurements

29 The principal determinations which must be made in a road test of a locomotive are:

(*a*) The engine and driving-wheel dimensions for horsepower calculations
(*b*) The leading boiler dimensions such as grate surface, heating surface, and boiler volume, which enter into calculations involving coal and water consumption
(*c*) The operating conditions such as throttle and reverse-lever positions, which define test conditions
(*d*) The speed
(*e*) The indicator diagrams for the determination of horsepower and engine conditions
(*f*) The temperature of the outside air, the feedwater, the superheated steam, and the front-end gases
(*g*) The boiler pressure
(*h*) The draft in the front end
(*i*) The quality of steam in the dome
(*j*) The weight of the feedwater and the weight of water and steam lost or used, through leaks, auxiliary apparatus, etc.
(*k*) The weight of coal fired
(*l*) The weight of the ash
(*m*) The chemical analysis and calorific determination of the coal
(*n*) The composition of the front-end gases
(*o*) The blackness of the smoke
(*p*) The drawbar pull
(*q*) The dimensions and determinations which may be required in connection with such auxiliary apparatus as may constitute a part of the locomotive undergoing test
(*r*) The length and weight of train, number and kind of cars, distribution of loaded and empty cars in train, and pertinent or unusual conditions regarding lubrication, braking equipment, etc.
(*s*) Wind, weather, and rail conditions.

Owing to the difficulties ordinarily encountered in locomotive road testing it will in general be found inadvisable to make observations concerning certain of the items mentioned unless conditions therefor are especially favorable and extreme care in connection with such observations can be exercised. The advisability of making observations concerning the following items should be considered:

Quality of the steam
Weight of the ash
Composition of the front-end gases
Blackness of the smoke.

Instruments and Apparatus

30 For road tests it is assumed that a dynamometer is available for registering the amount of the force applied to the train by the locomotive. The use of a dynamometer practically assumes the use of a dynamometer car. A dynamometer car, aside from housing the dynamometer, provides a convenient place for the installation of other measuring, indicating, and recording devices. The code as written provides that in general the testing apparatus will be carried on the locomotive itself. Where a dynamometer car is available a considerable portion of the testing equipment may be advantageously mounted within that car. Certain institutions have dynamometer cars which are available for test purposes and a considerable number of railroad companies own and operate dynamometer cars.

31 The apparatus and instruments required for a road test of a locomotive are:

(*a*) Dynamometer for determining the pull on the drawbar
(*b*) Weighing apparatus for fuel and ash
(*c*) Weighing apparatus for water in order to establish a calibration of the tender water tank
(*d*) A suitable arrangement of graduated gage glasses or floats on the tender tank for measuring the feedwater
(*e*) Water meters for measuring the feedwater
(*f*) Graduated scale attached to the water glass of the boiler
(*g*) Suitable levels or plumb lines to show the inclination of the boiler
(*h*) Pressure gages, draft gages, thermometers and pyrometers
(*i*) Speed-measuring apparatus
(*j*) Steam-engine indicators with indicator rigging or reducing motion
(*k*) Steam-sampling apparatus and steam calorimeter
(*l*) Coal-sampling apparatus
(*m*) Fuel calorimeter
(*n*) Air-pump stroke counters
(*o*) Some portable weighing or measuring apparatus for the determination of water losses or leaks such as injector overflow.

32 Additional directions regarding the use, the calibration, and the accuracy of the instruments mentioned are given in Pars. —— and —— of the code section on Instruments and Apparatus.

Preparation

33 In general, the preparations as given for the laboratory tests should be carried out preparatory to placing the locomotive in service with the understanding that some special directions regarding the installation of the testing appliances which refer to road tests should be followed. Par. 13 and sub-paragraphs 13*a* to 13*j* which relate to preparation for laboratory tests, should be studied.

34 The following directions relate to location of apparatus and special requirements for road tests:

(*a*) The water meter should be attached to the suction pipe of the injector at a point where it can be conveniently read when the train is in motion. A check valve should be provided to prevent hot water backing through it when starting and stopping the injector. A strainer should also be provided.

(*b*) The indicator rigging should be particularly rigid and suited to severe service under road conditions without liability to disarrangement during a test. Light tubing should be used to transmit the reduced motion to a point near the indicator. Lack of room and facility of operation make it desirable to use a single indicator for each cylinder, connected to the two ends by three-way cock. The piping to the indicators should be not less than $^3/_4$ in. inside diameter. It is best to carry the pipes to the side of the cylinder opposite the clearance spaces rather than to the cylinder heads or to the steam ports. A branch leading to the steam chest should be provided. Sharp pipe bends should be avoided, and the outside piping should be protected to avoid radiation. Rigidity of the indicator cock is essential and it should be obtained by clamping it securely to the cylinder.

(*c*) Unless suitable coal-weighing apparatus can be installed upon or near the tender, the coal must be weighed previous to the test and be so arranged upon the tender, by sacking or otherwise, that an accurate record of the coal used may be obtained. Coal taken en route should be delivered to the locomotive with such care that serious error concerning its weight may not occur.

Extreme care and watchfulness are necessary at all times in order to obtain reasonably accurate coal determinations. The method of sacking a part of the coal is one of the most convenient methods for determining the amount of coal used. Under this method all coal to be used should be weighed previous to the test upon scales known to be accurate. The greater

part of the coal, including that taken on route, may be placed in bulk upon the tender in the usual way. The remainder, say, 15 to 20 per cent, is to be placed in sacks containing 100 lb. each. The sacked coal should be used previous to the start of the test, after the close of the test, and preferably during the latter part of the test. It is desirable that all of the bulk coal be consumed during the test; if this is not done the remaining bulk coal must be carefully weighed back.

35 To facilitate the work of the men who operate the indicators and read the instruments at the front end of the locomotive, and to protect them from wind and rain and the jolting of the locomotive, a suitable housing or pilot box should be provided which should extend back to the cylinders and should be securely fastened to the bumper beam. The floor of the pilot box must be above the level of the pistons in order to minimize the danger to the operators in case of such accidents as broken piston rods or broken cylinder heads.

36 Steam used for auxiliary purposes other than in the cylinders such as air pumps, blower, calorimeter, injector overflow, train lighting and heating, and what escapes from the safety valves may be estimated from data obtained by testing such items of apparatus either before or after the trial and from records of the time of their operation or other pertinent data taken during the test. Test data regarding the use of steam for auxiliary purposes should always be taken with sufficient detail and completeness that errors arising from estimates of this kind will be small. If important auxiliary apparatus directly connected with the economical performance of the locomotive, such as the feedwater heater, is part of the locomotive equipment, such auxiliary apparatus should be tested during the trial in accordance with the A.S.M.E. codes applicable to the particular auxiliary apparatus.

37 The coal should be sampled at the time that it is weighed, in the manner provided for in Pars —— to —— of the code section on Fuels. Too much emphasis can hardly be placed upon the importance of proper fuel sampling. In case water is added to the coal after it has been weighed and sampled, a record of the approximate amount of water added should be made. Chemical analyses and calorific determinations of the coal sample are to be made in accordance with Pars. —— to —— of the code section on Fuels. The code for road tests does not provide for the collection of stack cinders, nor for sampling and analyzing ash or cinders. It is only under favorable circumstances that the ash can be collected with sufficient accuracy to warrant so doing. In case that provision is made for collecting ash and cinders and subsequent determinations are desired, the material collected should be sampled, analyzed, and have calorific determinations made in accordance with the instructions for similar determinations as presented in the code for laboratory tests.

Operating Conditions

38 Determine what the main operating conditions are to be and note the information and directions given in Par. 19 of the General Instructions. In a road test the operating conditions are in general those pertaining to the regular service on the railroad. The same general considerations concerning uniformity of conditions will govern during road tests as for laboratory tests in so far as may be possible. The nature of the service performed will, however, preclude the possibility of uniformity in a number of conditions in respect to which practical uniformity can be maintained in laboratory tests. Particular skill or other qualifications of the engineer and fireman may have an important bearing upon test performance, and conditions of this kind should be noted and in general made matters of record. The sanding appliances of the locomotive should be in good condition and slipping of the engines should be avoided where possible.

39 It is often desirable to take special readings of water levels and total weight of coal fired at specified stopping and passing points. Observations should be made throughout the trial of the time of passing mile posts or other designated points; the time the throttle valve is open or closed; the time of arriving at and leaving each station; also the length of time the stoker, safety valve, blower, train-heating system, lighting system and other steam-using apparatus are in operation. A record should be made of the number of injector applications and the overflow water should be measured or estimated and allowed for.

40 If during a run a stop of more than 5 minutes is made a deduction from the total amount of coal fired shall be made in determining the amount of coal used on the test. The amount of coal fired during such a stop should be determined as accurately as possible by firing the coal from a special supply such as sacked coal or by computing the number of scoopfuls of coal fired during the stop. In case the amount is determined by the number of scoopfuls, an average weight of one scoopful of coal should be determined previous to the test for the fireman and for the particular scoop which is to be used. During stops the fire should be maintained in proper condition according to the requirements of the service and as far as possible so that there may be the same amount of unconsumed coal upon the grate at the end of the stop as there was at the beginning of the stop. There should, preferably, be no water supplied to the boiler during stops, and a marked variation in boiler pressure should be avoided. If leakage or other conditions consume appreciable or readily measurable amounts of water during stops, allowance should be made therefor. For stops of less than 5 minutes' duration no allowance will be made for the coal consumed during such stops, and in general no allowance need be made for steam used or lost unless such uses or losses are of considerable magnitude.

Starting and Stopping

41 Consult Pars. 16, 17, and 18 of the General Instructions. The fire having been thoroughly cleaned, built up from a clean grate, or from a properly banked fire, it should be brought to about the thickness that will be required for the run. When the locomotive first starts with its train, observe the fire conditions, steam pressure, water levels, location, and time, and record the latter as the start of the test.

42 During the run the fire should be maintained as level and as uniform as practicable, and when the end of the run is reached the fire should have approximately the same quantity of unconsumed combustible upon the grate as at the start of the test. When the locomotive makes the final stop of the test with its train, the fire, if not already in the desired condition, should be quickly brought to approximately that condition in order to facilitate the determination of the amount of coal burned.

43 When the locomotive makes the final stop of the test with its train, simultaneous observations should be made upon steam pressure, water levels, location, and fire conditions, and the time recorded as the close of the test.

44 In general, it is extremely desirable that the fire conditions be so maintained as to permit substantially the same amount of combustible upon the grate at the start and at the close of the test. Except where fire conditions at start and close of test are known to vary greatly, no correction on this account should be applied in determining the amount of coal burned. The effort should be made to make the difference in unconsumed combustible on the grate, as between the start and close of the test, comparatively small, and to record fire conditions at these times with as great exactness as possible. Where a correction is applied on account of an important variation in fire conditions the final report should show the amount of such correction and the method by which it was determined. It is also, in general, desirable to close a test with the same or practically the same steam pressure and height of water in the boiler as obtained at the start of the test.

45 If the test is to include the complete run of the locomotive, including terminal operations, modifications concerning the handling of the fire, keeping the records, etc. will be required in order to provide for such extension of the test period.

Duration

46 The duration of a road test depends largely upon the length of the run and the service conditions. In general, for freight locomotives a test should not be materially less with regard to time and service than is required in operating over an average freight division. Every effort should be made that errors arising from inability to accurately measure coal and water may not constitute an unduly large percentage of the total coal and water determined. The duration of the test or running time is the elapsed time after the locomotive first starts with the train until the train comes to rest at the designated stopping place, minus the time consumed in

stops. In fast passenger service the runs should be, if practicable, at least 100 miles long.

Records

47 The data should be recorded in the general manner pointed out in Pars. 20 to 30 of the General Instructions, bearing in mind the fluctuating character of the load which often obtains, and that unusual precautions must often be taken to secure accurate information. Through suitable signaling or recording devices the taking of indicator diagrams or other observations such as steam pressure, lever positions, etc., made upon the locomotive may be recorded upon the dynamometer-car chart and coördinated with the time, location, and drawbar-pull records. If the conditions of the proposed test give promise of substantial uniformity and the test is to be of many hours' duration, observations should be made at 10-minute intervals, the drawbar-pull diagram marked at these times, and indicator diagrams taken. If the test is to be of short duration or the fluctuations of power or speed are extreme, shorter intervals should be used; or irregular intervals may be chosen such as will give data most representative of test conditions.

48 Special attention must often be given to matters which will make accurate tonnage records possible, and provision must be made that special conditions concerning wind, weather, track and equipment conditions are adequately recorded.

Calculation of Results

49 The results should in general be calculated in accordance with the methods given in Pars. 19, 20 and 21 of the code for laboratory tests. The code for road tests does not call for all of the data called for by the code for laboratory tests and the same refinement with regard to corrections is not always possible in connection with road-test data that may be desirable in connection with laboratory-test data.

50 Item 17(*a*), Length of Run, equals the total distance over which the locomotive moved the train. This distance is preferably determined from an autographic record showing the distance traveled by the train. Such a record is ordinarily made in connection with the record of drawbar pull. If such a distance record is not obtained Item 17(*a*) should be identical with or determined from Item 22(*c*), Equivalent Length of Run. Item 17(*a*) is to be used in calculating Item (20*i*), Number of Car-Miles, and Item 20(*j*), Number of Ton-Miles. For definition of the terms "ton-miles" and "car-miles" see Par. — of the code section on Definitions and Values.

51 Item 18, Duration of Test or Running Time, is the actual time between the start and stop of the test minus the time consumed in stops. Item 18 is to be used in all calculations leading to the expression of results of coal and steam consumption per hour, and individual determinations of i.hp. or d.hp. leading to average values for i.hp. and d.hp. are to be so selected that the average values will correspond to the time defined by Item 18.

52 The average drawbar pull should be determined preferably from a continuous record of the drawbar pull. If an integrating device is not a part of the recording apparatus, the area of the dynamometer record should be measured by means of a planimeter and this area divided by the length of the record; or the height of the record should be measured directly at a sufficient number of points to give a fair average result. The code provides that the drawbar horsepower is to be calculated from the average drawbar pull. Where it is found desirable to calculate drawbar horsepower for certain instants as at the time certain indicator diagrams are taken, the corresponding drawbar pull should be determined by direct measurement of the dynamometer record for the instant under consideration. The maximum drawbar pull should be measured as an average over a portion of the record which includes at least one revolution of the driving wheels. Items 50 and 51 of the Road Test Code should be calculated in the same way as Items 50 and 51 of the Laboratory Test Code. These items so obtained, however, have a somewhat different significance from those obtained in laboratory tests.

Final Report

53 The data and results should be reported in accordance with the form (Table 2) given herewith. A profile of the route over which the test has been made, showing the principal grades, curves, water stations, etc., should accompany the records of the test. Dynamometer records or selected portions thereof may also become a part of the final report. If records of the throttle and reverse-lever positions are not automatically obtained, it is usually desirable to obtain records showing the position of these levers at certain times during the test, and a report concerning such observations may become a part of the final report. Pars. 36 and 37 of the General Instructions present information regarding the form and substance of a final report.

TABLE 2 DATA AND RESULTS OF ROAD TEST OF LOCOMOTIVE

A.S.M.E. Code of 19—

Note: The first 16 items of this table are identical with the first 16 items in Table 1. When complete this table contains these 16 items.

Date, Duration, Etc.

(17) Date..........
 (*a*) Length of run .... miles
(18) Duration of test (running time) .... hr.
 (*a*) Actual time between start and stop .... hr.
 (*b*) Number of stops ....
 (*c*) Time consumed in stops .... hr.
(19) Coal, kind and size ....
 (*a*) Method of firing ....
 (*b*) Firebed, approximate thickness .... in.
(20) Gross weight of train, excluding the locomotive .... tons
 (*a*) Number of cars ....
 (*b*) Number of axles in train behind tender ....
 (*c*) Open-top cars ....
 (*d*) Closed cars ....
 (*e*) Kind of cars (give in such detail as may be desirable) ....
 (*f*) Loads ....
 (*g*) Empties ....
 (*h*) Average weight per car .... tons
 (*i*) Number of car-miles ....
 (*j*) Number of 100 ton-miles ....
(21) Kind of service ....
 (*a*) Weather conditions ....
 (*b*) Wind conditions ....
 (*c*) Rail conditions ....

Speed

(22) Revolutions of driving wheels per minute ....
 (*a*) Revolutions of driving wheels, total for running time ....
 (*b*) Speed equivalent of r.p.m. .... miles per hour
 (*c*) Equivalent length of run .... miles
 (*d*) Piston speed .... ft. per min.
 (*e*) Maximum train speed .... miles per hour

Boiler Performance

Average Pressures, Temperatures, Etc.:

(23) Temperature of feedwater .... deg. fahr.
(24) Temperature of steam in branch pipe .... deg. fahr.
 (*a*) Outdoor temperature .... deg. fahr.
(25) Temperature in smokebox .... deg. fahr.
(26) Boiler pressure, gage .... lb. per sq. in
 (*a*) Branch-pipe pressure .... lb. per sq. in.
(27) Draft in smokebox, front of diaphragm .... in. of water
 (*a*) Draft in smokebox, back of diaphragm, below superheat damper .... in. of water

Heating Value and Analysis of Coal:

((28) Heating value per pound of coal as fired .... B.t.u.
 (*a*) Heating value per pound of dry coal .... B.t.u.
 (*b*) Heating value per pound of combustible .... B.t.u.
 Proximate Analysis of Coal as Fired:
 (*c*) Fixed carbon .... per cent
 (*d*) Volatile matter .... per cent
 (*e*) Moisture .... per cent
 (*f*) Ash .... per cent
 (*g*) Sulphur, determined separately .... per cent

Analysis of Dry Smokebox Gases by Volume:

(29) Carbon dioxide (CO_2) .... per cent

Smoke:

(30) Percentage of smoke as observed .... per cent

Ash:

(31) Total ash collected from ashpan .... lb.
 (*a*) Ash collected, per cent of total dry coal fired ....
 (*b*) Ash by analysis, total .... lb.
 (*c*) Ash collected, per cent of ash by analysis ....

Continued on page 625)

CORRESPONDENCE

CONTRIBUTIONS to the Correspondence Department of MECHANICAL ENGINEERING are solicited. Contributions particularly welcomed are discussions of papers published in this journal, brief articles of current interest to mechanical engineers, or comments from members of The American Society of Mechanical Engineers on activities and policies of the Society in Research and Standardization.

The Design of Segmental and Sector Counterbalance Weights

TO THE EDITOR:

The following very convenient formulas for the design of locomotive counterbalance weights of both the segmental and sector forms were devised by H. A. F. Campbell and Emery Walker, of the Baldwin Locomotive Works, and are here presented, together with their derivations, by Mr. Campbell's kind permission.

In Figs. 1 and 2 let

- r = crank radius in inches
- R = outer radius of counterbalance in inches
- R_1 = inner radius of sector counterbalance in inches
- t = thickness of counterbalance in inches
- w = weight of a cubic inch of metal in counterbalance, in pounds
- W = weight at crank pin to be balanced, in pounds
- n number of spaces between spokes to be filled by sector counterbalance
- N = number of spokes in wheel.

Referring to Fig. 1, let l = length of arc ACB subtending the angle $AOB = 2\theta$ radians. Then since

$$\text{area of sector } OACB : \frac{\pi}{4}(2R)^2 : : l : 2\pi R$$

$$\text{area of sector } OACB = \frac{\pi R^2 l}{2\pi R} = \frac{Rl}{2} = \frac{R \times 2R\theta}{2} = R^2\theta$$

The distance of the centroid of the sector $OACB$ from O is

$$\frac{2}{3} R \frac{\sin\theta}{\theta}$$

hence the moment of its area about O is

$$R^2\theta \times \frac{2}{3} R \frac{\sin\theta}{\theta} = \frac{2}{3} R^3 \sin\theta$$

The area of the triangle OAB is

$$\frac{2R\sin\theta \times R\cos\theta}{2} = R^2 \sin\theta\cos\theta$$

and the distance of its centroid from O is

$$\frac{2}{3} R \cos\theta$$

hence the moment of its area about O is

$$R^2 \sin\theta\cos\theta \times \frac{2}{3} R\cos\theta = \frac{2}{3} R^3 \sin\theta\cos^2\theta$$

The difference of these moments is the moment of the area of the segment ABC about O, or

$$\frac{2}{3} R^3 \sin\theta - \frac{2}{3} R^3 \sin\theta\cos^2\theta = \frac{2}{3} R^3 \sin\theta\,(1 - \cos^2\theta) =$$

$$\frac{2}{3} R^3 \sin^3\theta = \frac{2}{3}\left(\frac{AB}{2}\right)^3 = \frac{2}{3}\,\frac{AB^3}{8} = \frac{1}{12} AB$$

hence the moment of the weight of the segment about O is

$$\frac{1}{12} AB^3 tw = Wr$$

and

$$AB = \sqrt[3]{\frac{12\,Wr}{tw}} \quad \ldots\ldots\ldots\ldots\ldots\ldots [1]$$

Similarly in Fig. 2, the difference of the moments of the areas of the sectors OAB and $OA'B'$ about O is the moment of the area $A'ABB'$ about O, or

$$\frac{2}{3} R^3 \sin\theta - \frac{2}{3} R_1^3 \sin\theta = \frac{2}{3}\sin\theta\,(R^3 - R_1^3)$$

hence the moment of the weight of $A'ABB'$ about O is

$$\frac{2}{3}\sin\theta\,(R^3 - R_1^3)tw = Wr$$

and

$$R_1 = \sqrt[3]{R^3 - \frac{3Wr}{2\sin\theta\, tw}}$$

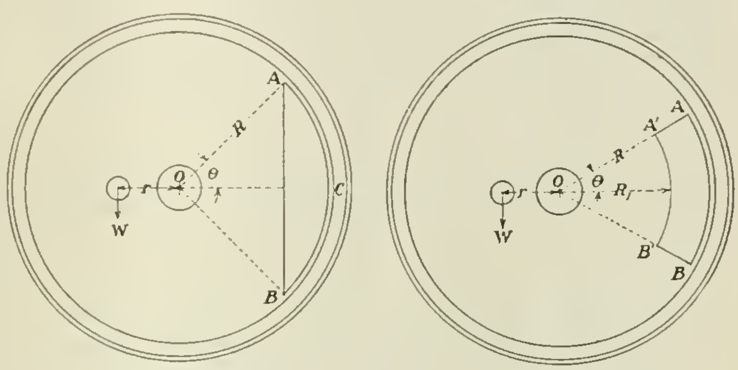

Fig. 1 Fig. 2

FIG. 1 SEGMENTAL-TYPE COUNTERBALANCE WEIGHT

FIG. 2 SECTOR-TYPE COUNTERBALANCE WEIGHT

Substituting for θ radians its sexagesimal equivalent of $\theta°$, then since

$$2\theta° : 360° : : n : N$$

$$2\theta° = 360\,\frac{n}{N} \quad \text{or} \quad \theta° = 180\,\frac{n}{N}$$

and

$$R_1 = \sqrt[3]{R^3 - \frac{3Wr}{2tw\sin\dfrac{180\,n}{N}}} \quad \ldots\ldots\ldots\ldots [2]$$

In applying these formulas t should be assumed.

The writer disclaims all credit for the foregoing beyond that of arranging the expressions and making the drawings.

Formula [1] can be applied to the design of the crescent type of counterbalance weight by determining the length of the chord AB of a segmental counterbalance for the given values of W, r, t and w, and after selecting the radius of the inner arc of the crescent counterbalance, by trial locating the center of this arc so that it will intersect the chord AB at such points that the area cut by the arc from the segment at the central part of the chord will be approximately equal to the sum of the areas added by the arc to the segment at the extremities of the chord, thus maintaining the volume and weight of the counterbalance approximately constant.

While this procedure is of course not accurate, since it ignores the alteration in position of the center of gravity of the counterbalance due to the change of its inner contour, it is thought that it will be found useful for purposes of preliminary design.

New York, N. Y. EDWARD L. COSTER.

A.S.M.E. Boiler Code Committee Work

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and simultaneously published in Mechanical Engineering.

Below are given the interpretations of the Committee in Cases Nos. 391, 399 (reopened), 416, 419, 421 and 422, as formulated at the meeting of June 26, 1923, and approved by the Council.

In accordance with the Committee's practice, the names of inquirers have been omitted.

Case No. 391

Inquiry: Permission is requested, under Par. 245, to operate water-tube boilers with the tubes secured to malleable iron headers at pressures greater than 200 lb. per sq. in. Also, attention is called to the fact that Par. 246*b* requires that the hydrostatic test be applied to all headers with tubes attached, whereas in certain cases it is not customary to attach the tubes until the boilers are erected in the field.

Reply: It has been proposed to revise the requirements of the Boiler Code in regard to the pressure allowance on water-tube boilers when the tubes are secured in malleable iron headers, as follows

"Par. 245—Change '200 lb.' in the third line to '350 lb.'

Par. 246*a*—Add the following to this section:

The malleable iron used for headers of water-tube boilers shall conform to the Specifications for Malleable Castings given in Pars. 111–120 (the paragraphs to be changed to conform with latest A.S.T.M. Specification).

Par. 246*b*—Change '1500 lb.' in the third line to '2250 lb.' Change the last sentence to read:

A hydrostatic test applied to all new headers or elements with tubes attached shall be 500 lb. per sq. in. when cast iron headers or elements are used, and two and one-half times the working pressure when malleable iron is used, although the minimum test pressure with malleable iron headers or elements shall be 500 lb. per sq. in."

Case No. 399 (Reopened)

Inquiry: (*a*) Is any allowance permissible in the value of T in the formula in Par. 199 of the Code, for the combined thickness of the head and washer applied on the outside thereof under the nut of the through stay, when the washer is of large size and riveted to the head?

(*b*) Is the same increase in the value of T in the formula in Par.199 applicable when a doubling plate is riveted on the inside of the segment of a head as if it were riveted on the outside of the segment?

Reply: It is the opinion of the Committee:

That the Code does not stipulate whether the doubling plate shall be placed on the inside or outside; it is optional, but the inside plate of your design is preferable;

That the doubling plate must cover the entire segment and be riveted to the head in accordance with the requirements of the Code;

That 75 per cent of the combined thickness of head and doubling plate shall be used in determining T;

That the value of $C = 175$ may be used for washers without doubling plate when stays are fitted with inside and outside nuts and outside washers, where the diameter of the washers is not less than $0.4p$ and the thickness not less than T;

That $C = 175$ may be increased by 15 per cent when both washers and doubling plates are used, designed in accordance with the Code;

That the Code does not provide any additional value for C on account of the washers being riveted to the plate.

Case No. 416

Inquiry: Information is requested as to the method of calculating, under the Rules in the Boiler Code, the required thickness of the bottom plate of the combustion chamber of a wet-back Scotch marine type of boiler when this bottom plate is curved upward or inward to the form of an arched surface between the points of attachment of the different furnaces and thus requires no staying.

Reply: It is the opinion of the Committee:

That there is no rule in the Code exactly covering the construction submitted;

That the rule which has been followed from the General Rules and Regulations provided by the Board of Supervising Inspectors Steamboat-Inspection Service, Department of Commerce, is not applicable to the design submitted;

That the application of this rule to the case in hand does, however, provide a safe construction. Par. 239*a* of the A.S.M.E. Boiler Code may be used, which is equivalent to the Board of Supervising Inspectors' rule above quoted;

That a safer construction would be obtained if the arch curved plate were either stayed to the outer shell or reinforced;

That it would be better construction to build boilers with separate combustion chambers, with the bottoms so designed that they need not be stayed.

Case No. 419 (In the hands of the Committee)

Case No. 421

Inquiry: Is it permissible to electrically weld a boiler shell, particularly the longitudinal joint, if sufficiently reinforced with bands as shown in the blue print, so that no stress is carried by the welded joint?

Reply: It is the opinion of the Committee that a boiler so constructed would not meet the Rules in the Code unless the bands are made strong enough to withstand the full boiler pressure without giving any credit to the holding power of the welded shell, and unless some other method than the autogenous welding shown in the blue print is used for attaching the heads to the shell (see Par. 186 of the Code).

Case No. 422

Inquiry: Will it be acceptable, under the Rules of the A.S.M.E. Boiler Code, to use angle-iron attachments for the heads to the shell of cylindrical boilers, instead of the American practice of flanging the heads, and also to bolt the furnace front sheet and the rear tube plate to the boiler heads instead of riveting?

Reply: It is the opinion of the Committee that provided the design is in accordance with the requirements of the Code as to material, stresses, construction, workmanship, inspection, and stamping, the boiler so constructed would meet the requirements of the Code.

Bending Stresses in Curved Tubes

(Continued from page 582)

As a second example consider the cross-section[1] represented in Fig. 2. In this case

$$h_1/h_2 = 1;\ b/a = 0.785;\ \lambda = 2640$$

The connecting angles and the external parts of the horizontal plates have no appreciable influence on the distortion of the cross-section, therefore the moment of inertia of their cross-section is included in the moment of inertia i_2. In this way

$$i_1 = 319 \times 10^3\text{cm.}^4;\ i_2 = 307 \times 10^3\text{cm.}^4;\ i_2/i_1 = 0.96$$

Substituting this in [5] gives $\beta = 0.60$. It is seen that in this case the maximum stresses and the flexibility of the tube are $1 : 0.60 = 1.67$ times those given by Formulas [1] and [2].

[1] Fairbairn crane described in Ernst's Die Hebezeuge, vol. iv, p. 540.

The Control of Civil Aviation

(*Continued from page 576*)

Some very interesting proposals for the carriage of mail to remote points, now served with difficulty, have been considered and within a few years air mails will undoubtedly be started. There is at present a United States Post Office contract for the conveyance of mails to a Canadian port to catch outgoing steamers bound for the Orient. This has worked out regularly and smoothly for two years now and is evidently giving satisfaction. It is operated by an American firm on the Pacific Coast. Their machines have been approved for the purpose of entering this country by the Controller of Civil Aviation.

In the event of any accident occurring the Department must be notified and an inquiry is held if considered necessary. Certificates of any class may be suspended at any time for cause by the Department, and this action is taken when the evidence before a court of inquiry points to negligence on the part of the holder. A return must be made to the Department annually, giving any particulars in regard to their operations which the Department may require. This enables reliable statistics as to passengers and freight carried, hours flown, etc., to be compiled.

It will be seen from the foregoing that a system has been instituted giving adequate control of the new form of transportation without undue interference by the state. A word is necessary as to the enforcement of the regulations, the examination of machines and personnel, etc. The inspectors should in all cases be practical flying men with the requisite experience and qualifications to undertake this class of work. If others not so qualified are employed, confidence cannot be maintained in the administration. If, on the other hand, the commercial firms feel that practical men, whose flying experience is beyond question, who understand their difficulties and problems, and who are personally interested in the development of flying, are charged with the administration of the regulations, confidence in the administration is easily gained and maintained. Too great emphasis cannot be laid on the necessity of employing the proper type of inspector.

Conclusion

Similar regulations have been passed by many countries and the experience of the past three years proves that the basis laid down in the International Convention for the control of aviation is sound. There are, and will be, many points on which differences arise owing to the widely varying conditions found in different parts of the world. The International Commission has been instituted for the very purpose of their discussion and settlement, and provides a medium for the mutual exchange of opinions and the settlement of divergent views. The success, under practical working conditions, of the code adopted under the Convention is testimony to the foresight and practical imagination of its framers.

A word may be permitted in conclusion regarding the situation in the United States. Canada and the United States are so closely allied, our interests hold so much in common, and our intercourse is so intimate, that an agreement on international flying between the two countries is essential. As no legislation has been passed so far in the United States providing for the control of aviation, it has not been possible to draw up a convention. The Canadian Government has, however, taken the necessary action in regard to the International Convention to permit such a convention being arranged, in that a derogation has been obtained in favor of the United States from Article 5 of the Convention, which limited our freedom of action in respect of non-contracting states. The government is also supporting an amendment to the same article to permit separate conventions with non-contracting states to be entered into. Canada admits all American machines on the same terms as if the United States had ratified the Convention. That is, we only insist that American machines entering and flying in Canada shall comply with the same regulations as our own. They are not, however, permitted to engage in the carriage of goods or passengers between two Canadian points or other commercial work. Aeronautical opinion in the states has expressed itself with the greatest emphasis on the desirability of passing legislation for the Federal control of aviation. This will be enacted without doubt in the near future. Its necessity must be evident to all. The bills now before Congress show no divergence in essentials from the terms of the International Convention. Some international agreement is essential and whether or not the United States eventually become a party to the present Convention, it is earnestly hoped that the authorities charged with the control of aviation will take no step which will tend to create different standards of control throughout the world from those adopted in Canada and elsewhere. Absolute uniformity is neither necessary nor desirable, but all will agree that a common basis for control and a common set of standards will be of inestimable benefit and will greatly facilitate the growth and progress of commercial aviation.

Preferred-Number Series

(*Continued from page 588*)

4 *Series for General Machine Construction.* The numbers in these series may be used whenever possible in general machine construction and especially for details not yet standardized, with the purpose of bringing about an automatic standardization of such details.

It is clear that quite a number of these series belonging to the four fundamental groups should be alike. A certain connection between some of the series ought to exist. For example, the series for normal diameters, group 3, ought to include all of the numbers in groups 1 and 4 which are employed for the selection of diameters. The series for lengths, group 2, could easily be unrelated to other groups.

Most of the existing standardizing bodies have devised standard series for diameters. The purpose of these series is to reduce the number of gages for finished diameters to a minimum, but they are also applicable to rough diameters for the purpose of saving patterns.

Any standard series must evidently be devised so that it can be followed under all circumstances, and at the same time so that as many numbers as possible may be left out. Thus far the series for normal diameters that have been worked out in different countries are very similar. The general character of these series is that they contain all the whole numbers between 1 and 20, all numbers ending in 2, 4, 5, 6, 8, and 0 between 20 and 50, all numbers ending in 2, 5, 8, and 0 between 50 and 100, all numbers ending in 5 and 0 between 100 and 200, and all numbers ending in 0 between 200 and 500. In addition some of the series for normal diameters contain other numbers intended for special purposes. The Austrian, the Swiss, and the Swedish series contain the numbers 37 mm. and 47 mm., to be used only in connection with ball bearings, these numbers being internationally employed as outside diameters of ball bearings. The diameters in the S. I. thread system are generally inserted in the series, and some of these should be used only for this special purpose.

It has been stated above that the numbers between 20 and 50 in the series for normal diameters end in 2, 4, 5, 6, 8, and 0. This use of the intervals 1 and 2 makes the series seem somewhat irregular. Further, the part of the series between 50 and 100 has the intervals 2 and 3. These irregularities, however, are unavoidable, due to the fact that our ordinary series of numbers is based on the number 10 and that we prefer to use numbers ending in 0 in the first place, secondly, numbers ending in 5, and thirdly, all even numbers. Evidently the series for normal diameters would have been more uniform and comprised fewer dimensions if the number 8 had been chosen as the base instead of 10. The author is of the impression that in this event the English inch system would have been changed by this time. As it is now, that system has a practical advantage over the metric system in the fact that the number 12 has a greater divisibility than the number 10.

There are many who argue that the number 12 should be employed as the base, and recently in Germany a change of system has been discussed. However, any such change is inconceivable, and we shall have to make the best of the mistake our ancestors made when they selected the number 10, and put up with the resulting larger number of normal diameters and uneven intervals in the standard series. And what is more, we shall have to deal with two different systems for measurements, the metric and the inch system, for an interminable period.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

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29 West 39th Street, New York

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Editor and Teacher

ON AUGUST 29, 1923, Fred R. Low completed his thirty-fifth year as editor of *Power*. During this long period of continuous service, which has been marked by fine courage and broad vision, has come about the stupendous development and use of power which has made this country great. Fred Low has taught, encouraged, and analyzed, always good-naturedly, but with strength, and has built up a journal of unmistakable influence and value in an important field of mechanical engineering. A profession cannot be greater than its teachers, and Fred Low must be numbered among the great teachers of the engineering profession.

Fred Low's ideals of service have been demonstrated by the conscientious manner in which he has performed his duties on many important committees of The American Society of Mechanical Engineers. His election to the presidency is a fitting recognition of work well done and a presage of his activity in behalf of the Society for many years to come.

The Earthquake in Japan

THE gripping feeling at the heart that came when the first news of the terrible catastrophe in Japan was received, has not been relaxed by the later and more accurate reports of casualties and property losses. The people of Japan have suffered and the help and sympathy of the world have been extended to them. The relief fund in the United States quickly rose to millions of dollars.

The frequency of earthquakes in the Japanese islands has been emphasized by this event, and those of us living in more favored localities have been surprised to learn that throughout Japan earthquakes may average three a day. It is interesting to note, however, that man has partially succeeded in coping with their destructiveness and that buildings constructed by American engineers to withstand earthquakes in a large measure weathered the recent shocks safely.

The reports of occurrences during the earthquake and its resulting fire and pestilence, and the accounts of reconstruction efforts, testify to the courage of the Japanese people. Fortunately the major portion of the empire's industry seems to be unharmed, and its industrial and engineering leaders face the situation calmly and bravely with the ample resources they possess of brains and money.

Uncle Sam A-Flying

IN THE last few weeks there have been several developments indicating in a welcome manner the remarkable progress that has taken place since the armistice by the flying branch of the American military establishment.

The first flying tests of the Navy dirigible *ZR-1* were carried out with apparent satisfaction. The new dirigible embodies not only the aircraft lore acquired during the war by engineers of the German Zeppelin Company, one of whom acted as consulting engineer to the Navy, but also the vast amount of information, experimental and theoretical, in the hands of American authorities at McCook Field, the Bureau of Standards, the National Advisory Committee for Aeronautics, etc. Thus, for example, as was pointed out in the September issue of Mechanical Engineering, the *ZR-1* is the first dirigible in which the distribution of pressure over the surface of the hull is actually known and not merely guessed at.

Another development in the same field was the maneuver carried out by the Army Air Service for the purpose of demonstrating that any point on the Atlantic seacoast from Maine to Florida could be furnished protection by aircraft within not more than seven hours. It is to the credit of the War Department that means were found to accomplish this end, notwithstanding the comparatively meager appropriations granted to this branch of the Army since the armistice.

The battleship-bombing tests off Virginia may not have been as spectacular as those of 1921 when the ex-German battleship *Oestfriesland* was sunk by a single bomb, but they serve as a further proof of steady advance in the development of this new form of warfare. In the recent tests attempts were made to hit the battleships *Virginia* and *New Jersey* from considerable altitudes, 10,000 ft. down to 3000 ft., and while the percentage of hits was not high enough to arouse any special interest, the fact remains that both battleships were sunk with gratifying promptness. While the tests have not shown that the battleship is truly obsolete in view of the development of the bombing airplane, they have nevertheless shown that control of the air by an enemy may be, and probably already is, of the most vital adverse significance even to the most powerful surface-fleet units. In other words, the American tests may be considered as having established the fact that naval warfare is already warfare in the air as much as it is on and under the surface of the sea.

In an article which will appear in an early issue of Mechanical Engineering some additional sidelights will be presented on the development of aerial warfare in connection with the growth of the Chemical Service.

International Conference Promotes Standardization Procedures

THE value of international contact in standardization matters was demonstrated in the second unofficial conference of representatives of various national standardizing bodies held at Zurich, Switzerland, July 3-6, 1923, at which there were representatives from thirteen countries, Austria, Belgium, Canada, Czechoslovakia, France, Germany, Great Britain, Holland, Italy, Norway, Sweden, Switzerland, and the United States. The conference discussed the possibilities of better intercommunication between the various national standardizing bodies, the interchange of reports, the organization of international efforts, and the methods for the practical utilization of standardization work. Messrs. Zollinger (Switzerland) and Le Maistre (Great Britain) acted as president and vice-president, respectively. The American Engineering Standards Committee was represented by Dr. Paul G. Agnew and the Canadian Engineering Standards Association by C. J. Durley.

The most important subject before the Conference was the interchange of information on work in progress. The Conference was unanimous in the view that the two principal phases of international coöperation are very distinct and should always be so treated, viz.: (1) Interchange of information, and (2) negotiations to bring about international agreement, i.e., international standardization. A free interchange of information can be of the utmost value to each country in its own work, saving multiplication of standardization and investigation, and paving the way for international agreement.

While the recommendation of the London Conference in 1921 provided for quarterly interchange of information on the status of projects, these reports are limited to a mere statement of progress, and there has been no general understanding as to the interchange of drafts of standards and of information relating to them.

After most careful consideration the following resolution was passed by the Conference:

> The Unofficial Conference of Secretaries, having noted the important progress already made in the interchange of information regarding work in progress between the various national standardizing bodies, requests each Secretary to submit to his organization: (1) The great desirability of making such information available, on request, to all the national bodies for use in their own work. (2) The interchange of draft standards as and when submitted for public criticism.

It will be noted that the first recommendation contemplates interchange on request only, the opinion being that the amount of expense and work involved in a complete scheme of interchange makes such a plan impractical at the present time; hence the limitation of making the information available on request.

The second recommendation has to do with the interchange of drafts of standards at the time they are published for public criticism. There is every reason to believe that the various sponsors will be glad to furnish a sufficient number of such copies for transmission to the foreign bodies.

Difficulties have arisen in the translation of certain technical terms of importance in standardization work. It was agreed that whenever trouble is encountered with such words, agreement on the best possible translations into English, French and German shall be reached by the secretariats in English-speaking, French-speaking and German-speaking countries, respectively. In this the clearing-house work is to be done for the present by the Swiss secretariat (since Mr. Zollinger was president of the Conference). These decisions will be circulated to all of the national bodies, the corresponding terms in other languages being added by the respective secretariats when they desire to do so.

At the London Conference in 1921 it was the unanimous opinion that the time was not ripe for a formal international standardizing body. As a result, it was informally agreed that, pending further experience, the experiment called "working centers," should be tried. An example will make the meaning clear. The Belgian Association being one of the bodies most interested in specifications for zinc and zinc ores, and having proposed international agreement on the subject, it was agreed that the Belgian Secretary should assume the duties of a secretariat for this subject, as if he were the secretary of an international body for the purpose, but in a much less formal way.

To carry on the work of the Conference it was decided to request the president of the Conference to proceed as if he were the executive officer of a loose association.

The Swiss Standards Association, acting as hosts, made very complete arrangements for the comfort and entertainment of their guests. Visits to a number of manufacturing establishments were arranged and at the conclusion of the conference a two-day tour was arranged from Zurich to the Jungfraujoch.

Blended Fuels

INCREASING attention is being paid to the subject of blended fuels, partly because of the possibility that some blend may be developed that will give increased power or engine efficiency, and partly also to relieve the ever-present threat of gasoline shortages in the future.

Professor Smallwood's investigation, published elsewhere in this issue, would seem to indicate, in general, that thus far the use of blended fuels has not led to any clear increase in the power developed by the engine, nor has it apparently produced any appreciable increased mileage per gallon, except with a heavily carbonized motor.

On the other hand, benzol is a smooth-burning fuel and when mixed with gasoline, even in comparatively small quantities, tends to suppress preignition knocks ("pinking"). Benzol also gives a somewhat better motor operation, so that blended fuel would appear to be worth perhaps two cents more per gallon than straight gasoline.

Tentative Program for First World Power Conference Is Announced

O. C. MERRILL, Secretary of the United States Federal Power Commission, returned late in August from a meeting in London relative to the World Power Conference which is to be held in London during July, 1924. Mr. Merrill is general chairman for American participation in the conference to which over twenty American engineering, technical, and industrial organizations have indicated already that they will contribute.

The objects of the World Power Conference will be to consider how the industrial and scientific sources of power may be adjusted nationally and internationally. Those arranging the conference propose to achieve this purpose as follows:

1 By considering the potential resources of each country in hydroelectric power, oil, and minerals;

2 By comparing experiences in the development of scientific agriculture, irrigation, and transportation by land, water, and air;

3 By conferences of civil, electrical, mechanical, marine, and mining engineers, technical experts, and authorities on scientific and industrial research;

4 By consultations of the consumers of power and the manufacturers of the instruments of production;

5 By conferences on technical education to review the educational methods in different countries, and to consider means by which existing facilities may be improved;

6 By discussions on the financial and economic aspects of industry, nationally and internationally; and

7 By conferences on the possibility of establishing a Permanent World Bureau for the collection of data, the preparation of inventories of the world's resources, and the exchange of industrial and scientific information through appointed representatives in the various countries.

The tentative program which was agreed upon at the London conference has been announced. All the papers to be presented will be printed and distributed in advance so that the entire time of the delegates at the meetings may be devoted to discussion. It is planned to feature a concise statement of the existing power situation in each country and to discuss conditions under which capital of one country can be invested in utility enterprises of another. A decided effort will be made to make the conference especially helpful to the professional engineer.

The conference will be conducted under five divisions, namely, power resources, power production, power distribution, power utilization, and general. The first division, that on resources, will be of interest to the whole conference and will comprise for each country a general survey of national power resources, developed and undeveloped; investigation of national power resources; power resources available and utilized; administration of power resources; and electrical power markets.

The sections under the second division deal with water-power production, preparation of fuels, steam-power production, internal-combustion engines, and power from other sources, such as wind power.

The division of power transmission and distribution will cover alternating-current transmission and distribution, high-voltage direct-current generation, transmission and distribution, and low-voltage distribution and electrical storage.

There are to be four sections on the utilization of power, i.e., power in industry and domestic use, power in electrochemistry and electrometallurgy, power for transport, and power for lighting and illumination.

The general division comprises a number of subjects which are likely to be of primary interest at the conference but do not readily lend themselves to classification in the other divisions. In many cases they are merely special aspects of subjects in the other divisions. One section will deal with economic, financial, and legal matters, and the other include such items as research, standardization, education, health, publicity, international coöperation, and permanent organization.

The executive committee for American participation includes representatives of government departments, the four national engineering societies, and other engineering organizations.

Constructive Reforestation Legislation Imperative

IN A STATEMENT prepared for the guidance of the member societies of the Federated American Engineering Societies, Colonel William B. Greeley, Chief of the United States Bureau of Forestry, warns that the predicted timber famine has already overtaken the eastern and central sections of this country. His summary of the situation is, in part, as follows:

Originally the United States contained five trillion board feet of stumpage; now, only one trillion, six hundred billion feet of virgin timber and six hundred billion feet of culled and second growth remain. Timber is being cut or destroyed at the rate of sixty billion board feet per year. Soft wood is being cut eight times as fast as it is being replaced, and hard wood three times as fast. Seventy-five per cent of all timber being cut is not being replaced.

Transportation is the key to lumber supply. Removal of the timber supply from points of consumption because of transportation charges has created retail prices so high that many demands for lumber cannot be satisfied. Twenty-eight states produce less lumber than they consume. In the space of seven years the average lumber haul between sawmill and consumer has increased 34 per cent.

There is probably not a single wood-fabricating industry east of the Mississippi and Northern Ohio and Potomac Rivers which does not today use wood distinctly inferior in intrinsic quality to that used twenty years ago. There is necessity now for teaching a vastly needed lesson of economy and of adopting new woods to old uses.

Grading of lumber must cease to be a matter of custom and become a matter of science. The consuming public must be furnished with exact knowledge of quality and forms of service forest products can render. The United States consumes about two-fifths of the forest products manufactured in the world.

Our per capita consumption of paper and other materials made from wood fiber has increased from 30 to 149 pounds in forty years. It about doubles that of England, the nearest competitor. National habits in the use of wood will have to be changed; the question is how much social and economic suffering will this change involve and what can be done to alleviate it. The per capita consumption in other countries is increasing, not decreasing. The demands in the United States are not going to decrease.

Ninety-eight per cent of rural dwellings in the United States are made of lumber. One of the crying needs in some agricultural sections is for better homes and the higher living standards which depend largely upon better homes.

The manifest requirements of the situation are:

First, make the timber we have go as far as it will through reducing waste and improving the efficiency of its use.

Second, make progress as rapidly as possible toward a permanent and sustaining supply of timber by increasing the growth in woodlands and by putting idle acres to work growing trees.

To sum up, the economic and social losses involved and the rapid depletion of the forests of the United States are so large and far-reaching as to challenge the attention of our most profound thinkers, to the end that there may be a more comprehensive plan for the elimination of waste in the growth and utilization of forest products and for reforestation.

In a letter from Charles H. McDowell, chairman of the Reforestation Committee of the F.A.E.S., the purpose of this committee is stated as being to direct the attention of engineers in particular and the public in general to the present serious situation due to national and state delay in passing constructive, workable and non-political laws for afforestation and reforestation, and to interest them in securing prompt legislative action.

In reviewing the present status of affairs, Mr. McDowell says further:

Lands suitable for the growing of forest products are owned by governments, corporations and individuals. Timber is a slow-growing crop, and the carrying charge of government-owned forests is a small one. This is not true of privately owned replanted cutovers or other forest lands. Interest charges on land values over the many years of tree development is a large item of cost. When taxes and interest on taxes over this period are added, there is no encouragement for new tree planting by companies or individuals. Many European countries assess only a nominal tax on growing forests and wood lots, but collect a tax from the income as these forest products are marketed. In many cases they require replacing of trees cut.

The tax load prevents aggressive forest planting both by companies and by individuals. Laws properly framed to protect the public but granting substantial tax exemptions on growing timber will go far in encouraging new tree planting.

There are many forest questions and policies which engineers can well study and report on, as for example, the policy of further acquisition of forests by federal, state and local governments and their method of coöperation with private owners of timber tracts that head waters may be protected, erosion minimized, fire patrols extended, and drainage controlled. Forestry schools should be encouraged by adequate appropriations so that the production of men skilled in handling the problems of reforestation would meet the needs.

Better care of forests, less wasteful exploitation, a fuller utilization of forest raw materials, timber preservation, minimizing of fire and tree-pest losses, are of vital interest to engineers and to the public.

The personnel of the F.A.E.S. Reforestation Committee is as follows: Hugh K. Moore, technical director, Brown Co., Berlin, N. H.; Dr. C. E. Paul, Armour Institute of Technology, Chicago, Ill.; C. G. Adsit, 555 Electric and Gas Building, Atlanta, Ga.; J. C. Ralston, 2421 W. Mission St., Spokane, Wash.; George A. Reed, State Engineer, Montpelier, Vt.; Theodore W. Norcross, U. S. Forest Service, Washington, D. C.; Dr. Raphael Zon, U. S. Forest Service, Washington, D. C., C. H. McDowell, Chairman, 209 W. Jackson Boulevard, Chicago, Ill.

Coal-Storage Survey Nears Completion

MEMBERS of the F.A.E.S. Committee on Coal Storage met in Chicago on August 27 and 28 to collate reports on different phases of the work which they have been carrying on during the summer.

The loss due to weathering has frequently been given as an argument against coal storage. Dean S. W. Parr of the University of Illinois, a leading authority on the chemistry of coal, gave facts proving that coal suffers only a slight deterioration in calorific value by exposure to air. Twelve years' experience with coal storage at Urbana has shown him that even the most volatile of central Illinois bituminous coal can be stored with but little loss, if proper methods are employed.

Methods in dock and pier storage, other than "head-of-the-lake" storage, were described by O. P. Hood, chief engineer of the United States Bureau of Mines. His statement included a report on storage by the Federal Government, with specific references to the Army and Navy and the Panama Canal.

A report on Duluth and Superior storage, where the greatest and most efficient storage plants in the world are located, was made by W. H. Hoyt, chief engineer of the Duluth, Missabe & Western Railway. Many recommendations of the committee will be based upon methods employed at these plants, which during the last coal year stored approximately 12,000,000 tons of bituminous and 1,500,000 tons of anthracite coal.

Among other special reports presented were the following: Mine Storage Location, by W. J. Jenkins, vice-president of the Consolidated Coal Company, St. Louis; Economical Use of Stored Coal, by David Moffat Myers, consulting engineer, New York City; Development of Storage Possibilities in Chicago, by E. S. Nethercut, secretary of the Western Society of Engineers, Chicago; Anthracite Storage, by R. V. Norris, consulting engineer, Wilkes-barre, Pa.; and Items of Transportation, by Roy V. Wright, editor of *Railway Age*.

The coal-storage survey represents one of the biggest concerted efforts of engineers that has ever been made in this country. Over a hundred sub-committees were formed for making local studies in cities in every state in the Union. These committees, consisting for the most part of five members each, are composed of leading local engineers representing national and local engineering societies and the various branches of the engineering profession. Operators, railway officials, and distributors have coöperated with the engineers, enabling them to assemble detailed information on the production, distribution, marketing, and consumption of coal. So far as possible the work of the local committees has been systematized by the use of a standard outline for their procedure and a questionnaire for the solicitation of information from different industries.

Dean P. F. Walker, field executive of the committee, who has been in close contact with the work of these sub-committees in many of the principal industrial centers of the United States, reported widely varying conditions, necessitating in many cases individual study and processes for the solution of the problem. Dean Walker advocated the establishment of large coke plants in industrial centers which would provide a substitute for anthracite and also supply cheaper gas for such communities. This plan would greatly facilitate storage, since coke is safe from spontaneous combustion, and would be of great value to the small consumer, especially the domestic consumer.

Before completing the survey another meeting of the committee will be held, probably in Washington. It is expected that all material for the report will be ready by December 1, and that the report will be released for publication early in 1924.

Phases of Industrial Management

Problems Confronting Executives in the Carrying On of Constructive and Productive Operations —The Qualifications of a Manager—The Financial and Business Side of Management

THE following twelve brief articles are extracts from papers presented at meetings of Local Sections of the A.S.M.E. held throughout the country during Management Week, October 16 to 21, 1922. They may be divided into three general groups, the first taking up the problems that confront an executive in the carrying on of constructive and productive operations, including the side of management having to do with human relations; the second dealing with the qualifications of a manager and requisites for success in management work; while the third concerns itself with the business and financial side of management.

Problems That Confront an Executive

Fundamentals an Executive Must Consider[1]

AN ENTERPRISE divides itself broadly into the following heads:

1 Engineering, in which is initiated the idea underlying the product, the scheme of the product itself, and the methods of making it.

2 Production, which deals with the actual work, the machines, and processes capable of turning out the product multiplied many times. Into this begins to enter the element of cost, for it must be considered not only how the production can be turned out, but how cheaply.

3 Sales. When the product is made, how can it be sold? This problem, which used to be left not so very long ago to the haphazard dealings of the loudmouthed, free-mixing salesman, is now rapidly becoming a question of scientific research. Modern merchandizing methods are not always founded on sociability, but they are founded on a close study of the needs of the community, and the problems of distribution are very many and very serious.

4 Labor Problems. Curiously, these have become in the last few years totally distinct from production problems. We are beginning to realize more than ever that we have a duty to labor. The old patriarchal idea which Carlyle writes about, and which obtained approximately during the middle of the last century, was that the workmen were children and the employer was a benevolent father who looked after them and provided them with the wherewithal; the children, however, had to do as they were told. Nowadays labor is demanding a partnership. The discussion is one that will go on for some years yet, but labor has to be dealt with each day on a newer plane.

5 Costs and Accounting. This is no mean problem: How shall we apportion our overheads? What does it cost to get the business? What does it cost to do the business? Are we getting enough for our product? How little can we take the business at and make a profit? And if we exceed that little, can we get the business?

6 Finance. This problem deals with the raising of the necessary money to start the business, to purchase the necessary workshop, the necessary tools, equipment, etc., to pay for the necessary help, the ever-pressing problem of the next payroll, the question of having bills paid promptly, and of receiving money promptly.

These are the six main problems that confront the present executive. Perhaps his biggest problem is to choose lieutenants who will operate in each of those divisions successfully, satisfactorily, relieving him of the responsibility to a large extent, and yet being able to keep him in touch with what goes on so that he can correlate their various activities and build up what is known as an organization. An organization is the human machine which through a process of time has demonstrated its ability to function smoothly and efficiently. The men forming the organization, while working as units, dovetail into one another harmoniously so that without conscious effort they understand not only their own position but their position relative to the whole organization.

Do I need to tell you that in each of these activities there are all kinds of details into which at times the manager is called upon to go? He must act many times as a judge, weighing evidence this way or that way, giving decisions which, like a judge, he must live up to in order to be respected, and in all ways try to be fair. It is unnecessary for him to have an intimate knowledge of each of those subjects, but he should have sufficient knowledge to be able to understand the problems of each department and to be able to reason intelligently with them to discuss them and to give decisions. It is necessary, therefore, for him to have a knowledge of what might be called the "fundamentals" of this work.

Carrying On Constructive and Productive Operations[2]

IN THE BUILDING of the constructive organization we have the problems of selecting the men, the problems of assembling and handling the materials, and the problems of determining definitely and conclusively what is to be accomplished.

We are concerned with a plant in any particular industry, its arrangement, the character of its equipment, the sequence, or order, of departmental operations, the arrangement of departments as related one to the other, the capacity of departments as related one to the other, and the location of the plant and its facilities for handling materials to and from the plant.

In the constructive as well as the productive organization we have to select the men best suited to each job and so arrange them that the product of one man's labor fits in with that of another, to the end that the best results from labor are obtained.

The arrangement of these men involves careful study with respect to grouping the men with their foremen or directing heads in charge of them. The making of the product has to be properly supervised and the work properly directed from day to day from the highest directing officer down to the lowest foreman in the organization.

From these necessities in connection with constructive and productive organizations, we can at once see that the management has three distinct functions to perform: It must first analyze the work it has undertaken to accomplish. It must then organize to carry it out, and must continue to direct and supervise the organization when built. We therefore have three functions of management—to analyze, to organize, and to direct.

Analysis of constructive and productive work is a most important function of management. The scheme of any industry as a whole must be taken apart and reduced to its simplest terms. We must determine definitely what we wish to do, what is to be accomplished, what is to be produced. Such analysis usually takes the form of putting on paper plans of the plant, showing in a general way the location of the necessary equipment, the arrangement of the plant, railroad tracks, and whatever other facilities may be needed in connection with it.

Having arrived at the point where analysis has enabled us to reach a definite decision in the matter of plans, we are now concerned in the organization to carry our plans through.

The building of an organization requires as much thought and as much time and study as does the planning; and, if neglected, may lead to excessive costs.

The directing head of an industry properly exercises full and complete control over all men in the organization, the results of whose activities he is responsible for. He has his assistants reporting directly to him and he issues his instruction through them. These assistants in turn direct superintendents in charge of departments, and superintendents report directly back to the assistants.

A superintendent of a department has his various general and sub-foremen. He properly issues his instructions to his general foremen and they in turn report directly to him, and the general

[1] John Younger, Mem. A.S.M.E., in a talk to students of Ohio State University.

[2] H. C. Ryding, Mem. A.S.M.E., in a paper read at a joint meeting of Electrical, Mechanical, and Civil Engineers in Birmingham, Ala.

foremen in turn issue their instructions to the sub-foremen, and the sub-foremen report directly to the general foremen.

An organization, therefore, is made up of a directing head, the assistants to a directing head, the superintendents reporting to an assistant directing head, general foremen reporting to a superintendent, and sub-foremen reporting to a general foreman.

The plan of this organization follows very closely the basis of a first-class military organization, and its procedure is also practically the same.

In the matter of instructions, no superior officer can afford to give a workman instructions other than through his foreman or superintendent. If he should do so, he relieves the foreman or superintendent, in whose department the workman is engaged, of all responsibility for carrying out the instructions given by him to the men. There is nothing that destroys discipline in an organization so quickly; and, as I have often said in discussing this subject with men interested in the question of organization, any fool can come in and break up an organization, whereas it takes a real man to build one up and maintain it properly.

In the maintenance of an organization, and presupposing that the best has been done to select men best fitted for the jobs, it is important that a well-defined scheme of promotion be established and understood, in a general way at least, by all subordinate officers. There is nothing that so encourages a man to do his best for you as to know that his efforts will be appreciated, and that appreciation is best shown by promotion when the opportunity offers.

A fair scale of wages is also a fundamental, and must at all times be thoroughly understood by all directing heads in any industrial organization.

Accuracy in timekeeping, accuracy in maintaining the individual rates in a wage schedule, is work of the highest importance and should properly be done at all times by men familiar with this particular class of work.

The pocketbook of the workman is his tenderest spot, and any touch there is very quickly responded to.

In directing the activities of an industry, simple and complex questions arise daily. Such questions may involve treatment of men, promotion of men, dissatisfaction on the part of an employee, and many others concerning the rate of operation or the inefficiency of perhaps a certain individual and inability of a department to turn out the product that it should turn out, and react unfavorably upon other departments.

All such questions must be carefully considered by the directing head of the activities of an industry. He should properly analyze the difficulties and when a conclusion is reached his instructions, in so far as it is possible, should be conclusive. I have often thought that inconclusiveness on the part of directing heads is one of the faults to which we do not give enough attention. Time is saved not only by the directing head but by the workmen when positive and conclusive instructions are given by the directing head.

If a matter can be settled at once, it is better to do so than to let it lie over, say, a couple of days before giving your answer.

Management and the Human Factor[3]

WHAT in brief has management to do? Successful management must satisfy the public, capital, and labor.

The Public desires five things in industry:

1 Stability
2 Adequate goods and services
3 Competent leadership
4 Some control in emergencies
5 Progress.

Capital desires the same five things in terms of:

1 Security of investment
2 Adequate production
3 Good management
4 Sufficient control of conditions affecting the risk
5 Expansion.

Labor's desires are very similar to the above, and obviously can only be obtained if the results desired by the public and capital are forthcoming. They are:

1 Steady employment
2 Adequate real wages
3 A good foreman
4 Individual and collective voice about conditions
5 A chance to rise.

If coöperation is possible, is the attainment of it probable? We believe that a large measure of benefit to the public and capital will accrue through seeing that the worker obtains in a satisfactory measure the five things just mentioned, and that he does so through democratic processes. We do not believe that these ends are inconsistent with those of the public and capital, for the latter at its best is just enlightened management, and with its industrial engineers it must answer satisfactorily this question: How are the masses of men and women, both without and with capital, to be taught to labor with their hands and brains willingly and efficiently that they may secure out of the products of their toil and their thought what they feel to be, and what will be in fact, a fair return?

Adequate incentive in professional opportunity and salary, and sometimes a possibility of a share in profit, must be forthcoming to secure the full services of the best ability both of direction and technique. Assumptions that the wheels of industrial direction can revolve solely under altruistic and "other-regarding" motives are vain. Such reformers should concentrate first of all upon human nature.

In the case of the wage earner, to remove the nightmare of unemployment from the workman's pillow; to carry any necessary surplus of labor of an industry at that industry's expense; to pay the highest possible wages; to improve the economic machine to that end; to lead, not drive, men by adequately trained and sympathetic executives who will command their respect and esteem; to provide for self-expression on all of the worker's interests and to keep the way open for his education and advancement and responsible participation; are measures both just and necessary and should be the basis of all industrial relations in coöperative industry.

The Psychology of the Situation. The nature of the relations between capital and labor as a whole at any time is determined by the quality of the relations between the individual employers and their wage earners. It is largely dependent upon their feelings about each other—is conditioned by a state of mind which arises out of the declared objectives of these two groups of human beings, and out of the moral and economic qualities of their intentions and conduct toward each other and toward society at large. This conclusion is the settled conviction of those who have come to know the workers and who spend their days in responsible direction of industry.

The Information Needed. Any helpful study must be more than descriptive. It must be practical and suggestive. It must not only uncover error, correct misunderstanding, and expose the vulnerable joints in our social armor—there are some people doing the latter without understanding and some with unhelpful intentions today—but it must reveal their true causes and, if possible, it must substitute constructive relations around common objectives.

It must analyze and measure—at least approximately—the feelings and conduct of labor and capital about all matters arising out of the employment relation. Unless this is done, unqualified statements on the subject, which are too common, lead to generalizations and assumptions about it which are not warranted, and to programs which give little help in the premises.

The Instruments of Capital. As we have seen, to make goods plentiful and men dear is calculated to satisfy the desires of the public, capital, and labor. In setting forth in some detail how management can best coöperate to this end and in the plant, the consideration of what capital should provide for this purpose is first in order. Adequate production under capitalism involves suitable means, material, and men, in well-balanced coördination with skillful direction, and operating under the conditions and incentives which secure a happy response from all concerned in the endeavor.

Workers are quick to sense the absence or existence of brainy, helpful provisions in equipment, system, and management for making the day's work expeditious, fruitful, and less fatiguing.

[3] John Calder, Mem. A.S.M.E., in a paper read at a meeting of the Chicago Local Section.

The Key Position of the Foreman. Assuming the existence of a good plant, the assistance of good planning for production, job analysis, time study, and all research essential to discovering the best about what can be done, where it can be done, how it can be done and by whom, we may ask what more in the premises management can do about organizing production among its own human factors.

The answer is that the moral, mental, and technical abilities of the non-commissioned officers of industry—the foremen, the men in front, the men next to the men who "deliver the goods"—should receive especial attention. In fact, too much emphasis can hardly be laid upon the necessity for raising the quality and performance of all supervision. Capitalism, however enlightened and progressive in intention and policy, must multiply itself through its minor executives who make the actual contacts with the employees. There is no other way, and there is no short cut even by this way.

Usually with fair technical competence, though often none too much, foremen—so far as being selected for executive ability is concerned—frequently "just happen," and when the date of the accession of the weaker ones to such a position is somewhat ancient and nothing has been done meantime to qualify them psychologically and in a humanitarian way for the job, the employer has "wished upon" himself, usually permanently, the incubus of the modern plant, namely, the "hard-boiled" executive. He is not always a foreman. The higher up he is the more harm he can do and the harder he is to reform. Too great stress cannot be laid upon the selection of executives and true measurement of their qualities and reasonable measures for developing their abilities. In the writer's belief this is much neglected in the case of the immediate supervisors of the workmen.

There are three principal ways of developing the foremen otherwise than as a technician:

1 Foremen training for production, with stress upon handling the human factors
2 Foremen training as interpreters of capital's industrial-relations policy
3 Foremen training as management representatives in councils.

Qualifications of a Manager—Requisites for Success in Management Work

Characteristics of the Successful Manager[4]

THE first of the qualifications which a successful manager should have is personality, three qualities of which are to be stressed, namely, (1) authority which springs naturally from a thorough knowledge of the jobs obtained through education, (2) physical and mental ambition and enthusiasm, and (3) affirmative assertiveness.

The second characteristic is the ability to judge men and their individual capacities. The third is patience and sympathy expressed through a willingness to receive employees and discuss their problems.

Fourth, the successful manager must be analytic and synthetic, with the ability to thoroughly analyze and organize his business into proper functions and departments. It is to be emphasized that the business must be organized on a progressive promotional basis so that each employee can see that by meeting certain standards, opportunity for promotion is ever present. This involves a definite training program so that every employee may grow in proportion to the time he remains with the organization.

The next qualification is the ability to create an *esprit de corps* in the entire organization. One factor in effecting coöperation is the taking of some interest in employees other than a purely factory or business interest. This can be done by means of a welfare program.

The last characteristic—and a very important one— is sincerity, without which failure is imminent. The manager is the source from which the organization draws its ideals.

[4] W. W. McLaureine, Professor Industrial Education, Georgia School of Technology, in a paper read before the Atlanta Local Section.

Requisites for Success in Management Work[5]

MY OBSERVATION tells me—and when I am telling you this it may be an unkind truth, but I am speaking of my intimate knowledge of men as a class, though there are exceptions, of course, to every rule—the average engineer lacks aggressiveness; he lacks in contact with the business world; he lacks positiveness and the ability to face the man of aggressiveness. This lack, I imagine, comes of his burning the midnight oil and his concentration of thought upon the greater things of engineering. I have seen engineers come before executive officers, filled with the best of ideas, with splendid thought and intent upon problems that they desire to have the management solve for them, who melt away and disappear because of the cross-questioning and the inquisitive minds of the men in charge of the organizations who must know for themselves exactly what is in those engineers' minds. There is not generally a comprehension in the mind of the engineer of the soundness of his own doctrine. He is not certain of himself. Management is nothing more nor less than certainty, absolute determination, and absolute knowledge and discrimination—intuitive, perhaps—of right or wrong. The man occupying an executive position must be one who can say yes or no to problems submitted to him without wavering or without showing any uncertainty. If he is dealing with engineering problems he must of necessity have an intimate knowledge of such problems; not, however, to the extent of being able to work them out but having an understanding of them, or else he should not occupy a position that brings him into contact with engineers. Because of the lack of aggressiveness and of positiveness engineers do not as a rule rise to those positions where they can command others.

Management consists in securing and retaining the love and affection of the men in the organization and their trustfulness in those superior to them. And yet there is no superiority in a real organization or in a company properly managed. All in it are on a level. Of course, some one man must at some time or other give the deciding voice on problems or policies, but when it comes to the particular duty of each part of the organization—I know whereof I speak, and some of my men here will confirm everything I say—they are taken into the confidences of the man who for the time being has a higher position, and they are listened to; they are allowed their voice, and very often allowed to make the decision in matters of importance. And above all, the thing that makes for successful management and successful organization is the trust that is reposed in those in power by the men below them in the line. There must be no jealousy or no feeling in the mind of any one of the men that some one else in the organization is getting the better of a position or a situation, or preferment in any way; and if you throw out jealousy and substitute loyalty, you have in my judgment a perfect organization, and perfect management.

Now, I am going to suggest to you engineers here tonight that if you expect to succeed in management, if you expect to get out of the groove in your chosen profession, if you are ambitious to rise to the top so that you may control men and things and events, you must throw off the restraint that holds you in its grasp. You must be ready and able to argue the questions that you believe in with those who doubt them. You must be ready to receive reproofs and rebuffs to the things that are nearest and dearest to your hearts, or the things that you think ought to be most considered and best considered by those to whom you are responsible. You must help the other fellow alongside of you, to pull him up if he is down, to raise him a little higher if he is deserving of it in your estimation. It is all human nature after all. Engineers are no better than nor different from any other class of men that I know, except that they have keener minds and greater vision. They are doers of things, they have their accomplishments. And by that they too often submerge themselves, because an engineer must be an artist to be a true engineer, and an artistic temperament is not combined with management or executive control. No man in that position can be an opera singer. He must have a tight jaw, a keen eye, and a decisive mind. Unfortunately, as a rule engineers do not possess those requisites unless schooled to them, or unless they possess a determination to succeed in that particular line.

[5] John A. Britton, Mem. A.S.M.E. (deceased), in an address delivered before the San Francisco Local Section.

Shortcomings of Certain Engineers in Management Work[6]

IT IS NO REFLECTION to recognize that many of the engineers that followed in the trail of such pioneers as Taylor and Gantt have failed in the fulfillment of their claims. Their chief weakness has lain in:

a Too great a generalization
b A lack of appreciation of "inertia" in human enterprises
c A lack of appreciation of the human element
d A lack of understanding of executive viewpoint
e A lack of knowledge of selling methods.

The chief error on the part of these engineers has been that they endeavored to reconstruct industry quickly by revolutionary methods in place of recognizing that the slower evolutionary method was the path by which the greatest progress would be made. There is a healthy index in the endeavor on the part of engineers through special study courses to attain a better understanding of business enterprise. The engineer has been unusually weak in that direction. His business equipment has been very close to the vanishing point, and as a consequence he has ignored the selling side, the financial side, and the human side of business enterprise.

The engineer's method of working from data in place of more or less indiscriminate observation is taking root, and it may be pointed out that there is no one better prepared as a whole to use data than the engineer, who, from the very beginning of his training is accustomed to acquiring data, analyzing data, and interpreting data.

The Business and Financial Side of Management

Deflation of Values in the Machine-Tool Industry[7]

In periods of great activity, and even under opposite conditions, it is always advisable to build machines in lots so as to get the benefit of quantity production. This may involve tying up considerable capital. It seems to me, however, that a plant must be very poorly managed if the gains due to quantity production do not more than balance the interest charges on the extra capital required to finance the larger inventory. Of course when deflation is quite drastic and when large stocks are carried, losses are inevitable, just as large profits result from this policy on a rising market. It is therefore apparent that no matter how scientifically the actual manufacturing operations are managed, the judgment to determine when to carry large inventories and when to reduce them as soon as possible will have more bearing on the ultimate success of the institution than scientific management may have had during periods of normal or greater acitivity.

The Retailer's Point of View[8]

TAKE the store that did the normal thing when prices were rising and manufacturers' representatives who visited the store said, "This is fine, this is a sellers' market....." This particular retailer placed orders for far more goods than he could possibly use, started pyramiding his orders; transportation facilities began to break down, for the railroads could not furnish cars. When the change in commodity prices started to come he found he had bought far beyond his needs and began to cancel orders. He was calling upon bank credit and straining it. He was calling upon manufacturers and wholesalers to furnish funds for his financing. He cut down his inventory prices—he had to clear out his stocks before he could buy more merchandise—and came to the bottom safe enough, because he didn't go bankrupt, but without cash and with a great fear of purchasing more goods, with the result that at the bottom he was buying from hand to mouth, when prices were low. He made no money but lost a great deal in trying to liquidate the large inventory which he had on hand.

Another store had a normal purchasing power of 35 per cent of the next season's demands of its departments. When prices began rising, they thought 35 per cent was too much, that prices were away out of line and could not continue. They began cutting down instead of increasing, first to 30 per cent and then to only 25 per cent, and started buying from hand to mouth. Instructions were issued that no order for more than $5 was to be given unless approved by the merchandise manager. When prices started to break they found that they had a comparatively small stock on hand. They took advantage of every price change during the decline, turned their merchandise rapidly, and made a small profit upon every turn. They increased sales because the public was looking for lower-priced merchandise, not less. When prices reached the bottom point, in the fall and winter of 1921, they bought 60 to 70 per cent of their business' demands..... Although there has been much criticism of the practice, I believe it is a wise thing to take profit upon replacement values rather than on costs.

The questions raised are, first, the statement that it is inevitable that the retailer must take losses; and second, if that is the case, how soon must it be after prices start to decline; third, that it is good business to take a mark-up on replacement value rather than cost on rising markets, and also good business to take losses..... The way in which the retailer can help most is by abandoning his normal buying habits and purchasing from hand to mouth as prices advance—when the tendency is to overstock and pyramid orders—and by buying more heavily—but not speculating—at the bottom of the price level when business needs the orders. If he does this he will relieve the strain of merchandise credits, will stop cancellations to a great extent, and in that way eliminate change of price levels. To do this he needs the aid of manufacturers, engineers, and others, and those individuals will find it to their particular advantage to reach a more conservative program... It is a question to know when and how prices are going to change... Retailers should start studying the relation of commodity prices to retail prices, the relation of raw-material prices to prices at retail.

Management and Sales Policies[9]

A SALES PROGRAM must be entirely dependent upon the management policy, to my mind. During a period like the present it is not a question of how much you can possibly sell, it is how much you can save yourselves. It has therefore been our policy to find out first of all how much merchandise we could safely dispose of and then try to confine our merchandise to the channels which were most loyal and most attractive so that we could give service through those channels. Our program, therefore, has not been one of seeking new customers, nor one of seeking new products to manufacture. It has been one of keeping the business of those customers whom we could serve during this period. During the slump to come some time in the next four years our program will be directly the reverse of this. Then we shall seek new customers, shall seek a new product and a new market for our goods.

The Relation of Bank Credits to the Business Cycle[10]

INITIAL EXPANSION in the first of a period of activity does not demand credit. It does not go on very far before it becomes necessary for business concerns, if they are to buy goods at rising prices, to secure additional credit. It was the granting of more credit that made possible the further upward movement of wool..... Is there any way of moderating bank credits? Not by means of legislation, because that would involve restrictions of banking activities. It has been proposed that some change be made in the currency standard, some adjustment in the weight and value of our gold unit to offset changes in price. That is very doubtful wisdom and will probably not appeal to the general intelligence..... Federal bank credits are too late to be effective. We must look to the policies in general of the commercial banks of the large cities, for they give the tone to the whole situation.....

Banks provide a portion of the working capital of most business concerns—they limit their appropriation, they determine what they regard as safe limits. Along with other items of information they secure balance sheets and income statements from business

[6] Max Slovsky, in a discussion of L. P. Alford's paper on Ten Years' Progress in Management at a meeting of the Tri-Cities Local Section, Davenport, Iowa.

[7] E. A. Muller, Mem. A.S.M.E., at a meeting of the Cincinnati Local Section.

[8] Prof. Donald K. David, of the Harvard Graduate School of Business Administration, in a paper before the Boston Local Section, at Cambridge, Mass.

[9] Howard Coonley, Mem. A.S.M.E., in a talk at the Cambridge meeting of the Boston Local Section.

[10] Prof. O. M. Sprague, of the Harvard Graduate School of Business Administration, at the Cambridge meeting of the Boston Local Section.

concerns, and determine a safe ratio, namely, that the inventory, receivables, and cash shall be twice the amount of the current liabilities. In some lines a smaller proportion will do; in others the bankers think the proportion should be higher..... My proposition is that in periods of activity and rising prices a banker should insist, or at least strongly advise, that his borrowing customers improve their ratio, and if during a period of business activity in a particular case a ratio of 2 to 1 is considered quite satisfactory, then he should try to convince the customer that after two or three years of rising prices a ratio of 3 to 1 would be none too large to secure the same degree of business stability and advise him to curtail and build up this ratio; in each year of good profits to furnish from his own resources a little more of the working capital of the business and rely less upon credits of one sort or another, even the banks. Prices would rise slower because houses would have less funds if credits were curtailed..... I cannot measure the effect of the adoption of such a policy, but I believe it would serve in more than one way to moderate conditions, and would be infinitely better than keeping going up to the last minute and then trying to "get out from under."

The Financial Statement as a Basis for Extending Credit[11]

Financial statements have not been, and never should be, the only basis for credit. They should not enter into the situation more than $33^1/_3$ per cent; the other $66^2/_3$ per cent should be made up of character, ability, knowledge of the business, experience, condition of plant, nature of line, prospects, etc..... Banks should insist on statements more than once a year, say, every three months or six months. An actual example of the disadvantage of having statements only once a year is that of a textile-manufacturing company which had quick assets and current liabilities in the ratio of 1.52 in 1916; 1.62 in 1917; 2.62 in 1918; 4.09 in 1919; 5.07 in 1920; in 1921 had 99 cents to pay every dollar of indebtedness and in 1922 but 72 cents. During the years 1916 to 1920 the net worth of the company was in excess of the total indebtedness in the ratio of 1.41; 1.42; 2.15; 2.82 and 4.55, indicating with an increase in the net quick assets a steady and heavy growth all along the line. In 1921 the statements showed 2.23 of debt for every dollar the company had in the business, and this has since gone to \$4.94. It is therefore believed that it would be advisable for all bankers to insist upon more frequent statements from borrowers.

Labor Shortage, Not Credit Stringency, Will Check Prosperity[12]

What is going to stop prosperity this time? Nor a stringency of credit, because this time our financial situation is utterly different from what it has ever been before in the history of this or any other country. The banks have ample loanable funds and are glad to make loans. They hold in their portfolios an amount of investments such as they have never known before and those investments can be turned into loanable funds on very short notice. In our Federal Reserve System we have a large part of all the gold of the world, and no country ever had the basis of such enormous credit expansion as there could be in America at the present time. So a lack of funds isn't going to stop this upturn, but it will probably come to a halt when American industries begin actively to compete with each other for labor. A labor shortage complicated by a shortage of railroad transportation—and the shortage of railroad transportation is already becoming serious—is beginning to show itself.

Now when these great up-turns or down-turns happen, very important changes take place in the mental attitude of labor. When prosperity is booming along, men rarely work as hard as they did before, but when a decline sets in they work much harder. That is one of those intangible elements in the problems of management that is of the very first importance.

In Akron in 1920 the average output of the automobile tire factories was substantially one tire per man per day. In 1921, with the same workers, the same factories, the same processes and same tires, the average output was 2.4 tires per man per day. In Detroit, in 1920, at the works of the Ford Motor Co., it took fifteen men working a day to make one car. In 1921, with the same machines, the same factory and the same men, eight men working a day made a car.

We are not yet able to avoid these swings. We are not going to be able to avoid them fully. We can mitigate them more and more as time goes on by finding out the facts by the scientific method, which, if I had to define it, I should say consists of analytical scrutiny, exact measuring, careful recording, and judgment on the basis of observed facts.

[11] F. S. Hughes, Manager Credit Dept., Federal Reserve Bank of Boston, in a paper read at the Cambridge meeting of the Boston Local Section.

[12] Colonel Ayres, Vice-President of the Cleveland Trust Bank, in an address at a meeting of the Cleveland Local Section.

A.S.M.E. Annual Meeting December 3-6, 1923

December 3 to 6 are the dates for the coming Annual Meeting of the A.S.M.E. The plans for the technical program which are being developed by the Professional Divisions of the Society in coöperation with the Meetings Committee indicate a meeting that will be of great value to the entire membership. In the field of power there will be three sessions, one devoted to heat balance and boiler-room economy, one on methods of water-flow measurement, and one on the various phases of coal storage. A joint meeting with The American Society of Refrigerating Engineers will discuss heat transfer, cooling towers, and insulation for refrigerating cars. The Machine Shop Practice Division is planning to discuss the principles of sheet-metal working. A research report in the machine-tool field will also be presented. Textile mechanical engineers will be treated to papers on steam distribution and woolen-mill construction; the Gas Power Session will deal with heavy oil engines; the Railroad Division will discuss steel car design and operation and the Aeronautic Session will treat the technical problems of commercial flying. The Ordnance Division has secured the coöperation of the technical staff of the U. S. Ordnance Department and two interesting papers are promised dealing with the advance in physical research in ordnance and the production of ordnance steel. The Management Division is planning two sessions, one devoted to the importance of good engineering as a preliminary step to the development of good management and a second on the subject of management in the public interest.

The *A.S.M.E. News* will contain complete information about plans for the meeting as they develop and members of the A.S.M.E. must read the *News* to get this information as no special circulars will be sent out this year. The complete program for the meeting will appear in the *A.S.M.E. News* for November 22.

The plans for the meeting have been under consideration for several months and all papers are expected to be in the hands of the Committee by October 1, so that proper steps may be taken for their publication previous to the meeting. The great value of a technical meeting lies in the discussion at the meeting and it is the ambition of the Committee on Meetings and Program to have papers issued so that all members may have an opportunity to prepare carefully considered discussions. Owing to the reduction in appropriations this year, all meeting papers cannot appear in Transactions in full, and concise, well-prepared discussions will aid the Meetings Committee in the conduct of the meeting and the Publications Committee in selecting material for Transactions.

The second Exposition of Power and Mechanical Engineering will parallel the meeting and last out the entire week. It is hoped that this arrangement will give the members of the Society a better opportunity to view the interesting exhibits at the Exposition. As the Exposition opens at noon each day, the Committee on Meetings is arranging to hold the sessions of interest to power engineers in the morning. The Exposition management has announced that already space of the entire first floor of the Grand Central Palace has been engaged and the exhibition space will therefore be extended to include the mezzanine floor. A division devoted to power transmission has been added to the Exposition.

The first exposition drew an attendance of 47,580 representative engineers, operating men, executives and financiers as well as technical students and their instructors, and the expressions of interest on the part of those attending and the words of satisfaction of those exhibiting were but a small measure of the success of the exhibition in informing the engineering public of the latest developments in the art of generating and utilizing power. The second show, with its greater size and diversity will undoubtedly be of greater value.

Engineering and Industrial Standardization

A.E.S.C. Approves Specifications for Wrought-Iron Bars and Plates

THE American Society for Testing Materials, in submitting their standard Specifications for Staybolt, Engine-Bolt and Extra Refined Wrought-Iron Bars, A84-21, for Refined Wrought-Iron Bars, A41-18, and for Wrought-Iron Plates, A42-18, state that the preparation of these date from 1905 to 1913, the first work in this field having been done on the first-named group of materials in 1905. The specifications for staybolt iron remained tentative for five years. In 1910 they were revised and adopted as standard by the society. In 1912 the requirements for strength, elongation, and reduction of area were slightly raised, and a new section on each test was included. The addition of a suitable vibratory requirement for staybolt iron has not yet been possible on account of the impossibility of formulating a standard method of test that could be adhered to strictly on any two existing types of testing machines. In 1917 the specifications for staybolt iron were revised extensively; in 1920 a revision was made in regard to the permissible variation in diameter, which was adopted as standard in 1921. The first specifications for engine-bolt iron were adopted in 1912, and, after a number of revisions, adopted in their revised form as standards of the A.S.T.M. in 1921. The tentative specifications for extra refined wrought-iron bars were developed in 1919, being designed to cover large rectangular bars used in the construction of locomotives and for similar purposes. These were adopted as standard by the A.S.T.M. in 1921, in which year the three sets of specifications for staybolt iron, engine-bolt iron, and extra refined wrought-iron bars were consolidated under the title given above.

The specifications for refined wrought-iron bars were first written in 1912, by the A.S.T.M. Committee A-2 on wrought-iron, being intended to cover a grade of iron suitable for general forging, smithing, and construction purposes. Following their adoption as standard, a number of revisions were made, and they were again adopted by the society in 1921.

The specifications for wrought-iron plates date back to 1913. Two classes of iron are provided for, in both of which it is specified that the material shall be free from any admixture of steel. The specifications stood without revision until 1918, when minor modifications were made. They have since been adopted as a standard of the society.

The special committee which recommended to the A.E.S.C. approval of these three sets of specifications as Tentative American Standards was headed by Col. E. C. Peck, representative of The American Society of Mechanical Engineers on the A.E.S.C. In addition the committee included representatives of the following organizations:

American Marine Association, Shipbuilding Standardization Committee
Department of Commerce
American Institute of Mining and Metallurgical Engineers
U. S. Navy, Bureaus of Engineers and of Construction and Repair
Association of American Steel Manufacturers
American Society for Testing Materials
Society of Naval Architects and Marine Engineers

This committee further recommended that the American Society for Testing Materials should be designated sponsor, under A.E.S.C. procedure, for the future development and revision of these specifications.

Twelfth Annual Safety Congress Meets in Buffalo Next Month

THE safety congress which is called each year by the National Safety Council will be held this time at the Hotel Statler, Buffalo, N. Y., October 1 to 5. The first edition of the program indicates that twenty-four of the N.S.C.'s sections will hold one or more sessions. Among these are the Automotive, Chemical, Cement, Construction, Education, Electric Railway, Engineering, Ice and Refrigeration, Marine, Metals, Mining, Packers and Tanners, Paper and Pulp, Petroleum, Public Safety, Public Utilities, Rubber, Steam Railroad, Textile and Woodworking. Under each of these heads two or more papers will be presented and discussed by leaders in the safety movement.

Two joint sessions are scheduled, one with the American Association of Industrial Physicians and Surgeons, and the other with the New York State Department of Labor.

LIBRARY NOTES AND BOOK REVIEWS

Bibliographies on Hydraulic and Wave Transmission

IN hydraulic transmission power is transmitted by a continuous flow of the liquid, while in wave transmission the liquid pulsates backward and forward about a mean position. Because of this distinction the references on the two systems are given separately, but in one or two cases, indicated by the title, both systems are discussed in the same article.

This list of references was compiled by Elizabeth Seymour, of the Engineering Societies Library. The articles are on file in the Library, which will supply photostatic copies of them at the rate of twenty-five cents a page.

HYDRAULIC TRANSMISSION

A New System of Hydraulic-Transmission, A. Raudot. Revue générale de l'Electricité, vol. 9, 1921, pp. 143–147; 177–181; 239–243; 279–284; 321–325. With this system it is possible to vary at will the output of a generator pump, driven by a primary motor at constant speed, between zero and a maximum dependent on the pump capacity.

Applications of Hydraulic-Transmission Variable-Speed Drive to Machine Tools and Manufacturing Processes, W. Ferris. Am. Soc. Mech. Engrs., Advance Proofs, 1922, 34 pp. Abstracts in Mech. Eng., vol. 45, Apr. 1923, pp. 238–241, discussion p. 211; Machy., vol. 29, Feb. 1923, pp. 496–497. Describes and illustrates a number of applications of the "Oilgear" to machine-tool driving, broaching, hydraulic presses, etc.

Das Lentz-Getriebe, Wittfeld. Maschinenbau, vol. 1, 1922, pp. 497–503. Problems of speed reduction and reversal with reference to electrical and mechanical systems and the Lentz hydraulic system. Various applications to railway cars, types of ships, etc.

Foettinger Transformers on a Liner. Engineer, vol. 134, July 7, 1922, pp. 4–5, suppl. plate opp. p. 12. Abstract in Mech. Eng., vol. 44, Oct. 1922, pp. 668–669.

Front Wheel Drive Truck Features Gearset with Hydraulic Control, B. R. Dierfeld. Automotive Industries, vol. 48, Apr. 5, 1923, pp. 759–762. Design of Lippische truck chassis now being produced in Germany.

Gasoline Switching Locomotive with Hydraulic Drive. Ry. Age, vol. 73, Aug. 19, 1922, pp. 323–326. Also in Ry. Mech. Eng., vol. 96, Sept. 1922, pp. 503–506. Abstract in Mech. Eng., vol. 44, Oct. 1922, pp. 666–667.

Hydraulic Power Transmission Gears, M. H. Sabine. Prac. Eng., vol. 65, 1922, pp. 151–154; 205–206; 221–222; 235–236. Abstract in Mech. Eng., vol. 44, 1922, pp. 320–321. Applications; particulars required for transmission and pump sets. Details of Williams-Janney, Carey pump, and Hele-Shaw systems.

Hydraulic Press with "Oilgear" Control. Am. Mach., vol. 55, 1921, p. 295.

Hydraulic Steering Gears, H. S. Howard. Am. Soc. Nav. Engrs., vol. 34, 1922, pp. 259–279. Gears fitted to the New Mexico, Tennessee, Maryland, and West Virginia. Diagrams.

Hydraulic Transmission, F. L. Martineau. Inst. Automobile Engrs., Proc., vol. 11, 1916–1917, pp. 223–258. Classification of transmission systems. Description of Hall, Janney, and Hele-Shaw transmissions.

Hydraulic Versus Electric Drive for Steel-Mill Auxiliaries, R. B. Gebhardt. Assn. Iron & Steel Elec. Engrs., Proc., 1919, pp. 85–96. Also in Engrs.' Club Phila., Jl., vol. 36, pp. 303–308. Applications to particular operations, including door hoists, furnace covers, elevators, manipulators, lifting tables, middle roll, balance shears, and intensifiers.

Oilgear—A Variable Speed and Feed Control System. Am. Mach., vol. 55, 1921, pp. 271–274. Abstract in Mech. Eng., vol. 43, Oct. 1921, p. 682–683.

Recent Types of Hydraulic Transmission Gear. Eng. & Ind. Management, vol. 7, Apr. 6, 1922, pp. 323–327. Describes Williams-Janney swash-plate gear, the Hele-Shaw transmission system, and the Constantinesco wave transmission gear.

Variable Speed Oil Transmission Gear. Engineering, vol. 114, Dec. 1922, pp. 800–801, and 801. Gear constructed by Oilgear Co., Milwaukee Wis.

WAVE TRANSMISSION

Dorman Wave Power Tools, Rock Drills, Rivetters, etc., for mining and shipbuilding. W. H. Dorman & Co., Stafford, England, 1920. Preface by Walter Haddon.

Hydraulic-Wave Transmission. Elec. Times, vol. 57, 1920, pp. 133–134. Wave and electrical transmission compared. Describes the Constantinesco system.

Romance of Wave Transmission, new world's industry for Britain, progress of great twentieth-century invention by a mining engineer. Reprinted from Eng. Suppl. of Overseas Daily Mail, Oct. 14, 1922.

Sur la Transmission de l'Énergie par les Vibrations de Liquides dans les Conduites, C. E. D. Camichel and A. Foch. Comptes Rendus, vol. 171, 1920, pp. 783–786. Authors claim initial pressures must be considerable and find Mr. Constantinesco's analogy between hydraulic and electric phenomena not theoretically correct.

Technische Schwingungslehre, Wilhelm Hort. Second Edition. J. Springer, Berlin, 1922.

Theory of Wave Transmission, George Constantinesco. Walter Haddon, 132, Salisbury Square, E. C. 4, London, 1922. A treatise on transmission of power by vibrations.

Wave Power Transmission, W. Dinwoodie. Paper read before Soc. of Engrs. Inc., 17, Victoria St., Westminster, S. W. 1, on Dec. 4, 1922.

Wave Transmission, a New and Sixth Method of Transmitting Power, Walter Haddon. Ed. 3, London, 1922 A descriptive pamphlet on the invention of G. Constantinesco.

Wave Transmission Patents. Walter Haddon, 132, Salisbury Square, London, 1922.

Trade-Association Activities

Trade Association Activities. Prepared by L. E. Warford and R. A. May, under the direction of Julius Klein, Director, Bureau of Foreign and Domestic Commerce. Government Printing Office, Washington, D. C. Flexible linen, 6 × 9 in., 368 pp., $0.50.

To increase the popular interest in the reorganization of the Department of Commerce, and to aid in the development of a definite program for the elimination of national waste, for the establishment of industrial research, the collection of economic information, and the promotion of foreign trade, the Department, in a comprehensive publication entitled Trade Association Activities, has focused attention on the possibilities of the organizations of producers or distributors of commodities or service, known as trade associations.

The volume is accredited to L. E. Warford and Richard A. May, directed by Julius Klein, Director of the Bureau of Foreign and Domestic Commerce under Secretary Hoover. Its preparation was undertaken jointly by the Bureau of the Census, the Bureau of Foreign and Domestic Commerce, and the Bureau of Standards, aided by a representative committee covering the many phases of trade-association activities.

Secretary Hoover, in an extended introduction, enumerates the various essential constructive services rendered by associations, and in summarizing states that if we are to have a comprehensive economic system, it seems the time has come when we should take cognizance of the necessities. The growing complexities of our industrial life, its shift of objective and service, require the determination of an economic system based upon a proper sense of rightful coöperation, maintenance of long-view competition, individual initiative, business stability, and public interest.

The book has an important purpose and is exhaustive, but a brief review of its contents would be inadequate. However, the following chapter headings are suggestive of the large and representative amount of material brought together: Statistics and Their Legal Aspects, Legislative Activities, Simplification and Standardization, Cost Accounting, Credit and Collective Activities, Trade Disputes and Ethics, Employee Relations, Insurance, Public Relations, Traffic and Transportation, Commercial and Industrial Research, The Government, the Department of Commerce, Organization and Administration of Associations, History, Directory of National and International Associations.

Bearing the stamp of the Government, the work is official, and from the representative method of its compilation it may be considered as authoritative. The price is nominal only, and every one engaged in industry and commerce owes it to himself to secure a copy from the Superintendent of Documents.

Applied Mechanics. By Alfred P. Poorman. Second edition. McGraw-Hill Book Co., New York and London, 1923. Cloth, 6 × 9 in., 293 pp., diagrams, $2.75.

A textbook for undergraduate courses in engineering schools. Departs from the usual procedure by making extended use of the graphic method of solution and by presenting a large number of illustrative examples which have been solved in detail to show the relation between the principle which has been developed and the problem to which it applies. Several changes have been made in the new edition and the section on statics has been expanded.

By-Product Coking. By G. Stanley Cooper. Second edition. Benn Brothers, London, 1923. Cloth, 6 × 9 in., 192 pp., illus., diagrams, 12s 6d.

An English treatise which aims to supply the need for a textbook by giving an accurate, up-to-date account of the industry as it stands at present. Considers the nature and preparation of coking coals, the development of the by-product oven, plant operation, oven systems, machinery, the recovery of by-products and the utilization of gas. Intended primarily for students, but useful also to practical men.

Caratteristiche Costruttive Delle Turbine Idrauliche Negl' Impianti Attuali. By Guido Gambardella. Antonio Villardi, Milan, 1923. Paper, 7 × 10 in., 133 pp.

In this contribution to the literature of the hydraulic turbine, the author is concerned with the correlation of recent theory and current practice, and with a comparison between the results of calculation and those obtained by laboratory tests. Theoretical and experimental data furnished by various manufacturers are given and modern features in distribution and regulation are explained. The book is intended for students who wish to understand current manufacturing practices, for purchasers of turbines and for manufacturers.

Costing and Price-Fixing. By J. M. Scott-Maxwell. Issac Pitman & Sons, New York and London, 1923. Cloth, 6 × 9 in., 211 pp., illus., $2.

The purpose of this book is to give briefly the general principles of cost accounting and, in detail, a complete system applicable to a factory manufacturing a large variety of apparatus, relatively to its total output, the great bulk of which cannot be completed and put into stock, but can be only partly manufactured and must be completed after the receipt of the customer's order. Appropriate parts of the system will meet all the requirements of factories that produce finished products and sell from stock, while the complete system can also be applied to plants that work to order only. The principles and system have been used by the author in practice for the past fifteen years.

Dock and Harbour Engineer's Reference Book. By Brysson Cunningham. Second edition. Charles Griffin & Co., London; J. B. Lippincott Co., Philadelphia, 1923. Fabrikoid, 4 × 6 in., 319 pp., diagrams, tables, 9s.

The subjects considered in this book are harbor and dock construction; quay and dock walls and wharfs and their equipment; locks, graving and floating docks and their equipment; dredging and subaqueous rock removal; maritime canals, channel rectification and demarcation, and coast defense. The volume does not attempt to be complete. It is based on notes made for his own use

by the author, and touches only lightly on theoretical considerations, being more concerned with particulars of works actually carried out and with their cost.

Les Economies de Combustibles; Conduite Rationnelle des Foyers. By Pierre Appell. Gauthier-Villars et Cie., Paris, 1923. (Encyclopédie Léauté, 2e série.) Paper, 6 × 8 in., 341 pp., illus., diagrams, tables, 17 fr.

The purpose of this book is to call attention to the economies in the use of fuel possible in industry and to indicate the methods by means of which these savings may be realized. The author reviews the fuel situation in France, gives directions for investigating and choosing fuels, explains the phenomena of combustion and discusses methods for using fuel efficiently under boilers, in gas producers, and in furnaces. Methods of measurement and control are also considered. A bibliography and index are given.

Electric Furnace for Iron and Steel. By Alfred Stansfield. McGraw-Hill Book Co., New York and London, 1923. Cloth, 6 × 9 in., 453 pp., illus., diagrams, tables, $5.

Instead of issuing a new edition of his Electric Furnace, Dr. Stansfield has decided to replace it by two new books, of which the present work, dealing with the use of the electric furnace in the metallurgy of iron and steel, is one. It is intended to give a reasonably complete account of the electric smelting of iron ores to make pig iron and the making of steel from metallic charges in electric furnaces.

The book consists of three parts. The first contains historical matter, an outline of ferrous metallurgy, and a brief account of the electrical supply needed for electric furnaces. The second part describes the electric smelting of iron ores for pig iron, the reduction of iron ores in the state of powder and the production of ferro-alloys. The third part treats of the production of iron and steel from metallic materials and the furnaces in use for these purposes. It also includes a chapter on the production of steel from ore and on electric welding.

Electrical Handling of Materials, vol. 4: Machinery and Methods. By H. H. Broughton. Ernest Benn, London, 1923. Cloth, 9 × 11 in., 334 pp., illus., diagrams, 50s.

This, the concluding volume of Mr. Broughton's useful treatise, has for its subject the machinery used for handling materials mechanically and the methods of handling and storing. The opening chapters describe elevators, conveyors, belt conveyors, automatic feeders, and ship hoists. Succeeding chapters are devoted to methods of handling various articles, especially, ore, coal, grain and similar bulk materials, and foodstuffs. Like the other volumes, this one deals broadly with the question of design and gives many examples that illustrate the present state of the art.

Elements of Machine Design. By Dexter S. Kimball and John H. Barr. Second edition. John Wiley & Sons, New York; Chapman & Hall, London, 1923. Cloth, 6 × 9 in., 446 pp., illus., tables, $4.

A discussion of the fundamental principles of design, intended primarily for students, but also, the authors hope, of interest to designers. The principal part of the work is devoted to the discussion of the more important details of machines, with a view of showing how theoretical considerations and equations are applied and modified in practice. The new edition has been thoroughly revised and the arrangement changed as a result of experience. A chapter on the balancing of machine parts has been added.

Financial and Operating Ratios in Management. By James H. Bliss. Ronald Press Co., New York, 1923. Cloth, 6 × 9 in., 396 pp., tables, $6.

In every branch of industry there are certain characteristic financial and operating ratios, depending upon the nature of its activities. The aim of this book is to develop certain standard ratios for the use of managing executives in securing more effective control of the finances and operations of their business.

Part 1 of the book considers the various ratios and turnovers which should be noted and compared; explains how they are computed and their bearing on the general problem. Part 2 contains tables compiled from published reports of representative industries, with explanations. These statistics afford standards enabling a company to compare its own statistics with standards within the industry and thus gage its competitive position. The book also aims to show the methods by which a concern may prepare standards in its own line.

Hydraulics for Engineers and Engineering Students. By F. C. Lea. Fourth edition. Edward Arnold & Co., London, 1923. Cloth, 6 × 9 in., 594 pp., illus., tables, $6.

Dr. Lea's book is intended as a reference book for practicing engineers and as a textbook for serious students. He attempts to deal with the subject in a wider sense than is done in most textbooks, to embody the results of the latest experimental research on the subject, and to give sufficient details to indicate the methods used in obtaining those results. This edition has been revised to include the latest experiments. The original chapter on turbines has been much enlarged and that on pumps has been divided into two chapters.

Die Leistungssteigerung von Grossdampfkesseln. By Friederich Münzinger. Julius Springer, Berlin, 1922. Paper, 6 × 9 in., 163 pp., illus., diagrams, tables, $1.

An active experience in planning and operating large boiler plants during the last ten years has led the author to certain opinions concerning methods for increasing the output and economy of large steam generators and to an appreciation of various difficulties that have had to be overcome. The results of his practical work are set forth in the present volume, which discusses the ways by which large boiler plants may attain greater economy. Special attention is paid to the influence of accessory apparatus. The concluding chapter considers possible future developments.

Mechanisms of Machine Tools. By Thomas R. Shaw. Henry Frowde and Hodder & Stoughton, London, 1923. (Oxford Technical Publications.) Cloth, 9 × 11 in., 351 pp., illus., diagrams, $14.

In the present work Mr. Shaw endeavors to place on record many of the essential principles which have a place in machine-tool design. The book opens with an account of the evolution, types and functions of machine tools, in which several examples of early design are shown, accompanied by later designs showing the changes. The materials are then discussed briefly. The remainder of the book discusses many of the more important mechanisms: gearing, frames, bearings, power transmission, reverse motions, controlling, tripping, indexing and locking devices. These, as far as possible, have been grouped as separate units, distinct from any machine, so that the reader may analyze the different methods in use for a single operation. The volume is unusually attractive in make-up.

Modern Ironfoundry. By Joseph G. Horner. Henry Frowde, & Hodder & Stoughton, London, 1923. Cloth, 6 × 9 in., 255 pp., illus., $5.

The work of an experienced founder, this book is intended for apprentices and young men who wish an insight into practical methods. Cupolas and their working, fans, blowers and tools are described; methods of molding are explained and the causes of faults in casting are shown. There are chapters on flywheel, and cylinder molding, on machine molding and die casting, as well as one on foundry design and equipment.

Le Moteur Humain et Les Bases Scientifiques du Travail Professionel. By Jules Amar. Second edition. Dunod, Paris, 1923. Cloth, 5 × 7 in., 690 pp., illus., tables, 45 fr.

Amar's book is a study of the mechanism of man as a motor, and of the way this motor works. It attempts to present all the physiological and physical data available for the scientific study of labor and for determining the efficiency of human work. Although the war has interfered seriously with scientific research during the nine years that have elapsed since the first edition appeared, some interesting investigations have been made, which have been incorporated in the new edition. New material is given on nutrition, physical training, locomotion, and on the measurement of sense perception, as well as on experimental methods.

Motor Boats. By F. Strickland. Isaac Pitman & Sons, London and New York, 1923. Cloth, 5 × 7 in., 116 pp., illus., $1.

A concise review, in non-technical language of the development and construction of motor boats, of the principles of the marine motor, of its advantages over the steam engine, and of its possible future development.

Power Plant Machinery, vol. 1; Mechanism of Steam Engines. By Walter H. James and Myron W. Dole. Second edition. John Wiley & Sons, New York; Chapman & Hall, London, 1923. Cloth, 6 × 9 in., 277 pp., illus., diagrams, $3.

In revising their textbook on the Mechanism of Steam Engines the authors decided to expand the work into a general discussion of the principal machines used in a steam power plant; of this work the present book becomes volume one. It is an elementary treatise on the kinematics of reciprocating steam engines and steam turbines, planned for students who take up the subject after a course in the elements of mechanism and before they study the theory and practice of heat engineering. An effort has been made to present the subject so that the beginner will understand the mechanical principles on which the engine operates, with special reference to the valve gear and governing devices, and the various diagrams used to study them. The aim is to treat these questions logically and concisely, yet with sufficient detail to make the principles easily understood.

Radiotelegraphie et Radiotelephonie a la Portée de Tous. By G. Malgorn. Gauthier-Villars et Cie., Paris, 1923. Paper, 6 × 9 in., 231 pp., illus., diagrams, 10 fr.

Most of the books on radio telegraphy and telephony have been written for those experimenters, amateur or professional, who wish to construct or assemble radio stations. The present writer addresses himself to that larger class of persons who purchase commercial radio sets ready for use, and who are interested only in understanding the principles of the apparatus and in learning how to use it most effectively. The book explains the theory of radio, the functions of the various parts of the receiving set, and supplies practical information on the operation and maintenance of the apparatus.

Wood-Preserving Terms. By Ernest F. Hartman and E. F. Paddock. Protexol Corporation, New York, 1922. Paper, 6×9 in., 85 pp., $1.

A useful glossary of terms used by wood preservers, including chemical, pathological and engineering terms, as well as those which are merely industrial. The definitions frequently are encyclopedic in fullness and accompanied by references to the literature, so that the pamphlet forms a convenient reference work.

Test Code for Locomotives

(*Continued from page 610*)

Coal and Rate of Combustion:

(32) Coal fired, total....lb.
- (a) Dry coal fired, total....lb.
- (b) Combustible by analysis, total....lb.

(33) Coal as fired per hour....lb.
- (a) Coal as fired per hour per sq. ft. of grate surface....lb.
- (b) Coal as fired per hour per cu. ft. of firebox volume....lb.
- (c) Dry coal fired per hour....lb.
- (d) Dry coal fired per honr per sq. ft. of grate surface....lb.

Quality of Steam:

(34) Quality of steam in dome....per cent
- (a) Superheat of steam in branch pipe....deg. fahr.

Water and Steam:

(35) Water evaporated, total....lb.
- (a) Water delivered to boiler....lb.
- (b) Weight of water in boiler at start of test minus weight of water in boiler at close of test, (plus or minus)....lb.
- (c) Boiler correction....lb.
- (d) Water losses....lb.
- (e) Moist steam used at auxiliaries, calorimeter, safety valve, steam leaks, etc., total....lb.
- (f) Superheated steam used or lost before reaching the engine cylinders, total....lb.

Evaporation:

(36) Steam to superheater per hour....lb.
- (a) Moist steam per hour....lb.
- (b) Heat transfer across water-heating surface per hour (units of evaporation)....1000 B.t.u.
- (c) Heat transfer across superheating surface per hour (units of evaporation)....1000 B.t.u.

(37) Total heat transfer per hour (units of evaporation)...1000 B.t.u.
- (a) Heat transfer per hour per sq. ft. of heating surface (units of evaporation)....1000 B.t.u.

(38) Units of evaporation per pound of coal as fired....1000 B.t.u.
- (a) Units of evaporation per pound of dry coal....1000 B.t.u.

(39) Superheated steam per hour....lb.

(40) Superheated steam per pound of coal as fired....lb.
- (a) Superheated steam per pound of dry coal....lb.
- (b) Superheated steam per hour per sq. ft. of heating surface....lb.

(41) Efficiency of the boiler and furnace (heat absorbed by boiler)....per cent

Engine Performance

(42) Steam delivered to the engines per hour....lb.
- (a) Coal-as-fired equivalent of the water and steam losses....lb. per hr.
- (b) Dry-coal equivalent of the water and steam losses....lb. per hr.

Events and Pressures from Indicator Diagrams, Average:

(43) Mean effective pressure....lb. per sq. in.
- (a) Cut-off....per cent of stroke
- (b) Steam-chest pressure....lb. per sq. in.
- (c) Initial pressure....lb. per sq. in.
- (d) Pressure at cut-off....lb. per sq. in.
- (e) Least back pressure....lb. per sq. in.

Indicated Horsepower:

(44) Indicated horsepower....i.hp.
- (a) Right side, head end....i.hp.
- (b) Right side, crank end....i.hp.
- (c) Left side, head end....i.hp.
- (d) Left side, crank end....i.hp.

(45) Coal as fired per i.hp. per hour....lb.
- (a) Dry coal per i.hp. per hour....lb.

(46) Steam per i.hp. per hour....lb.
- (a) B.t.u. of coal consumed per i.hp. per hour....

General Locomotive Performance

Drawbar Horsepower:

(47) Drawbar horsepower....d.hp.
- (a) Average drawbar pull....lb.
- (b) Maximum drawbar pull....lb.

(48) Coal as fired per d.hp. per hour....lb.
- (a) Dry coal per d.hp. per hour....lb.
- (b) Coal as fired per 100 ton-miles....lb.
- (c) Coal as fired per car-mile....lb.
- (d) Dry coal per 100 ton-miles....lb.
- (e) Dry coal per car-mile....lb.

(49) Steam per d.hp. per hour....lb.
- (a) B.t.u. consumed by engine per d.hp. her hour....
- (b) Steam per 100 ton-miles....lb.
- (c) Steam per car-mile....lb.

Efficiency:

(50) Indicated horsepower minus drawbar horsepower....hp.

(51) Ratio of d.hp. to i.hp....per cent

(52) Efficiency of the locomotive....per cent

Endurance-Test-Data Interpretation

(*Continued from page 581*)

after a certain length of time. Repeating the experiment with another crankshaft identical in every respect and made by the same concern, it would be found that the life would be very different from that of the first one. This was true of practically every manufactured product.

Failure of a steel part always started at a definite point, and upon examination it would be found that it was due to some small defect such as porosity or the presence of slag; for there was no steel that did not contain slag, although in most cases it was present in such minute quantities that it could be detected only by a high-power microscope.

Those purchasing tungsten lamps, ball bearings, gears and the like wanted to know how long they would last under certain conditions and would select those with the longest life because they would be cheaper in the end and safer. Tests had to be repeated many times in order to get comparative results on which to base the endurance and safety of a product.

The curves given in the paper would prove of value to the manufacturer in that they would reveal to him the amount of dispersion, which he could then reduce by painstaking inspection.

The reason why failures occurred was not always clear; it was known in some cases, but not in all. He would emphasize the fact that every endurance test should be run to a definite end point; if possible, to the point where failure started.

THE ENGINEERING INDEX

Registered United States Great Britain and Canada

Exigencies of publication make it necessary to put the main body of The Engineering Index (p. 113-EI of the advertising section) into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.

AIR FURNACES

Fuel-Oil-Burning. Using Fuel Oil in Air Furnaces, A. V. Landschoot. Iron Trade Rev., vol. 73, no. 9, Aug. 30, 1923, pp. 599–604, 2 figs. Proper combustion, close control of heat, attention to charge, and regulation of time element are factors in operation of oil-fired malleable-iron melting units. From paper read at Am. Foundrymen's Assn. convention.

AIRSHIPS

ZR-1. Building the Large Navy Dirigible ZR-1, F. E. Schmidt. Am. Mach., vol. 59, no. 10, Sept. 6, 1923, pp. 367–371, 9 figs. Outline of problem in designing and building huge airship; special machine for drilling holes spaced within two thousandths of an inch; machining duralumin.

AUTOMOBILES

Wheels. The Spring Wheel, C. P. Schwarz. Automobile Engr., vol. 13, no. 179, Aug. 1923, pp. 238–242, 18 figs. Inquiry into design and commercial possibilities; described as wheel having yielding or resilient elements intended to render road shocks harmless.

BEARINGS, BALL

Contact Area of Ball and Plate. The Contact Area of an Elastic Sphere When Compressed Between Flat Elastic Plates, John Goodman. Engineering, vol. 116, no. 3005, Aug. 3, 1923, p. 133, 4 figs. Methods of ascertaining area in contact between a steel ball and steel plates, and results of tests.

BEARINGS, THRUST

Michell. An Air Lubricated Michell Bearing. Engineering, vol. 116, no. 3007, Aug. 17, 1923, p. 203, 3 figs. Notes on model constructed by Albert Kingsbury, consisting of two parts, a solid collar about $5^1/_8$ in. in diameter and 1 in. thick and weighing about $5^3/_4$ lb., and a baseplate or stand on which are mounted three Michell pads, pivoted behind their centers of figure in accordance with Michell principle.

BOILER PLANTS

Economical Operation of. New Mac-Sim-Bar Boiler Plant Saves $100,000 per Year. Power vol. 58, no. 10, Sept. 4, 1923, pp. 352–356, 12 figs. How consumption of coal per ton of board has been reduced from 2200 lb. to about 1200 lb., production of board per 24 hours increased from 150 to 170 tons, and power-house payroll cut in two, at plant of Mac-Sim-Bar Paper Co., Otsego, Mich.

BOILERS

Pulverized-Coal-Fired. Powdered Coal Installation, Whitaker-Glessner Plant, Wheeling Steel Corp. Power, vol. 58, no. 9, Aug. 28, 1923, pp. 333–334, 4 figs. Describes powdered-coal boilers of new plant, and its equipment.

BRIQUETTING

Metal Turnings. Dust and Metal Briquetting. Iron Age, vol. 112, no. 8, Aug. 23, 1923, p. 475, 1 fig. De Gama process for recovery of metal turnings, blast-furnace dust and ore fines.

CASE-HARDENING

Steel. Carburization of Steel, B. F. Shepherd. Am. Soc. Steel Treating—Trans., vol. 4, no. 2, Aug. 1923, pp. 171–196, 21 figs. Study of continued use of carburizing compounds as it affects character of case produced; influence of increased carburizing temperature, effect of time variation, influence of time and temperature upon character of case, and relationship in carburized and hardened chrome-vanadium steel between scleroscope hardness, carbon content and penetrability as measured by Brinell method at different zones in case.

CAST IRON

Pearlitic. Pearlitic Cast Iron, O. Bauer. Iron Age, vol. 112, no. 7, Aug. 16, 1923, p. 412. New type of iron castings developed in Germany; use of hot-sand molds affects microstructure and properties. Abstracted and translated from Stahl u. Eisen, and discussed by Richard Moldenke.

CASTINGS

Testing Methods. New Testing Methods for Castings, E. Ronceray. Iron Age, vol. 112, nos. 7 and 8, Aug. 16 and 23, 1923, pp. 393–396 and 470–473, 20 figs. Discussion of elastic limit; modulus of elasticity; sound, compression and bar tests; comparisons with Brinell hardness; transverse and shearing tests recommended and tension and shock tests condemned. Paper presented to Inst. Brit. Foundrymen.

CHUCKS

Vacuum, Work-Holding. Holding Work by Vacuum, Charles O. Herb. Machy. (N. Y.), vol. 30, no. 1, Sept. 1923, pp. 12–15, 8 figs. Describes chucks, developed by Crescent Pump Co., Detroit, Mich., that utilize vacuum for holding large quantities of small pieces made of either ferrous or non-ferrous metals, and non-metallic work such as rubber, fabric, wood or glass, during machining operations.

CONDENSERS, STEAM

Testing. Testing Jet Condensers, L. Long. Power, vol. 58, no. 8, Aug. 21, 1923, pp. 293–296, 1 fig. Means of locating faults. Eroded or plugged injection nozzles, high temperature of incoming water, corrections for vacuum and barometer readings, and other points which come up in jet condenser testing, are described.

CORES

Mixtures for, Reducing Cost of. Cheapens Core Sand Mixtures, C. S. Koch. Foundry, vol. 51, no. 16, Aug. 15, 1923, pp. 665–670 and 685, 9 figs. Experiments said to indicate costs in shops making light steel castings can be reduced by using heap sand in cores; tensile-testing strength determines strength of dried mixtures. Paper presented before Am. Foundrymen's Assn.

CRANES

Gantry. Improved Gantry Cranes for the Port of Hamburg, Germany, E. Krahnen. Eng. News-Rec., vol. 91, no. 8, Aug. 23, 1923, pp. 296–297, 5 figs. Describes combination swinging and traveling cranes which increase cargo-handling facilities.

DIE CASTING

Problems in. Solving Die-casting Problems. Machy. (N. Y.), vol. 30, no. 1, Sept. 1923, pp. 51–52, 5 figs. Information obtained at plant of Atlas Die Casting Corp., Worcester, Mass., regarding problems of constructing die so as to produce casting with least difficulty, and obtaining accuracy in sinking die impression.

DIESEL ENGINES

Fuel-Consumption Test. Test of Diesel Fuel Consumption, W. B. Gregory. Power, vol. 58, no. 8, Aug. 21, 1923, pp. 285–286, 2 figs. Account of test undertaken for City of Crowley, La., to determine whether guarantees made by builders had been met.

GEARS

Steel for. Gear Steel. Automobile Engr., vol. 13, no. 179, Aug. 1923, pp. 232–237, 13 figs. Investigation of factors governing wear.

GRINDING MACHINES

Centerless. New Centerless Grinder. Iron Age, vol. 112, no. 8, Aug. 23, 1923, pp. 479–480, 3 figs. Shoulder and straight cylindrical work ground rapidly; 16 feed variations provided.

HYDROELECTRIC DEVELOPMENTS

California. Hydro-Electric Developments in California. Engineering, vol. 116, no. 3007, Aug. 17, 1923, pp. 210–212. Details of construction program which will bring about complete electrification of whole of North American Pacific Coast from San Diego to Vancouver, and in which American and Canadian enterprise will coöperate.

Hydro-Steam Electric Generation. The Paradox of Hydro-Steam, George Holmes Moore. Eng. News-Rec., vol. 91, no. 9, Aug. 30, 1923, pp. 354–356, 5 figs. Analysis to show that energy generated by combined steam and hydro prime movers can cost less than either one separately.

INSPECTION

Contour Measuring Projector. New Projector Measures Wide Range of Precision Parts. Automotive Industries, vol. 49, no. 8, Aug. 23, 1923, pp. 364–367, 9 figs. Describes contour measuring projector, an instrument developed by Bausch & Lomb Optical Co., for visual inspection of screw threads, forms of gear and cutter teeth, and other parts; accuracy of 0.0001 in. can be attained; separate attachments make photographs.

LABORATORIES

Locomotive. Locomotive Testing Laboratory, Robert H. Moulton. Machy. (N. Y.), vol. 30, no. 1, Sept. 1923, p. 6, 2 figs. Notes on equipment of laboratory of Univ. of Ill.; unique locomotive which runs under full steam and at same time remains stationary, is part of equipment.

LOCOMOTIVES

Repair. Repairing Locomotives in a Machine-Tool Shop. Am. Mach., vol. 58, no. 25 and vol. 59, nos. 1 and 9, June 21, July 5 and Aug. 30, 1923, pp. 893–896, 11–13 and 317–319, 26 figs. June 21: Shop located on main line; cranes and other handling equipment; all classes of locomotive repairs handled. July 5: Rod, valve and motion work; worn guides, crossheads and pistons built up with manganese bronze; welding broken frames. Aug. 30: portable floor and cylinder boring machines; repairing driving boxes; minor boiler repairs.

MOTOR TRUCKS

6-Ton. 6-Ton Motor Vehicle for Service at High Altitudes. Engineering, vol. 116, no. 3005, Aug. 3, 1923, p. 140, 14 figs. on supp. plate. Describes vehicle built by Halley's Industrial Motors, Ltd., Glasgow, for use at tin mines of Bolivia; has to work at altitudes of from 11,000 ft. to 15,800 ft. above sea level; six-cylinder engine of 5-in. bore and $6^1/_2$ in. stroke, which gives Treasury rating of 60 hp. and normal running speed is 1000 r.p.m.

OIL ENGINES

Kerosene. Two-Cylinder Parafin Lighting Set. Engineer, vol. 136, no. 3528, Aug. 10, 1923, p. 158, 2 figs. New Type of oil-engine-driven electric lighting set, having capacity of 10 kw. at 105 volts, and driven by engine similar to those made by same firm for motor boats.

PUMPING PLANTS

Bristol, England. The Cheddar Pumping Station. Engineering, vol. 116, no. 3007, Aug. 17, 1923, pp. 199–201, 3 figs. Data on station recently installed by Bristol Waterworks Co. to increase quantity of water available; contains three main pumping sets each consisting of a 5-stage Mather & Platt turbine pump geared to a 2-cylinder Ruston & Hornsby horizontal cold-starting airless-injection oil engine.

RAILWAY REPAIR SHOPS

Special Tools for. Special Tools in the Great Northern Shop, Frank C. Hudson. Am. Mach., vol. 59, no. 10, Sept. 6, 1923, pp. 351–353, 6 figs. Describes devices that save labor and expense in a railway repair shop.

SEMI-STEEL

Chemical Control. The Role of Chemistry in Semi-Steel, J. E. Bock. Iron Age, vol. 112, no. 7, Aug. 16, 1923, pp. 397–398. Chemical control of both raw materials and finished product necessary; role of combined carbon; effect of other elements.

Mechanical Characteristics. Mechanical Characteristics of Casting, Albert Portevin. Iron Age, vol. 112, no. 10, Sept. 6, 1923, pp. 610–614, 8 figs. Examination of semi-steel tensile and compressive strength, elasticity and shearing resistance, compared with its hardness; considers also semi-hard steel. Translation.

STEAM ACCUMULATORS

High-Pressure. The Steam Accumulator and Its Applications. Power vol. 58, no. 9, Aug. 28, 1923, pp. 322–326, 8 figs. Describes construction of high-pressure accumulator and shows how weights, capacities, etc., are figured; some possible applications.

STEAM TURBINES

Disks, Stresses in. Rotating Disks of Conical Profile, B. Hodkinson. Engineering, vol. 116, no. 3009, Aug. 31, 1923, pp. 274–275, 3 figs. Gives table which forms basis of practical method described of determining stresses in such disks; points out that for any given loading boundry stresses can without any simplification or further assumption, be put in by trial, easily, and with ample accuracy, and this complete solution obtained for practical disk.

Multiple-Exhaust, Tests on. Tests of the 15,000-Kw. "Multiple Exhaust" Turbine at Dalmarnock Engineering, vol. 116, no. 3009, Aug. 31, 1923, pp. 273–274, 2 figs. Results achieved with 15,000-kw.–18, 750-kw. turbine at Glasgow Corp. Power Station, Dalmarnock, where R. B. Mitchell had the enterprise to install this large unit in which K. Baumann's multiple exhaust was embodied.

STEEL CASTINGS

Battleship Turret Track. Steel Turret Track Castings, S. W. Brinson. Foundry, vol. 51, no. 16, Aug. 15, 1923, pp. 645–648 and 664, 8 figs. Methods and equipment adopted in Navy Yard foundry for molding, pouring and annealing battleship castings designed to meet severe chemical and physical specifications.

Heat Treatment. Heat Treating Improves Castings, A. E. Lorenz. Iron Trade Rev., vol. 73, no. 8, Aug. 23, 1923, pp. 534–535, 2 figs. Excellent results obtained with chrome-nickel steels; treatment exaggerates good and bad properties of material; more research on special alloy steel castings needed as their demand increases. (Abstract.) Paper presented before Am. Foundrymen's Assn.

Preliminary Strengthening Treatment. Making Steel Castings Tough as Forgings, L. R. Mann. Iron Age, vol. 112, no. 7, Aug. 16, 1923, 425–426, 2 figs. Preliminary treatment to produce homogeneity in austenite essential to ideal metal structure; alloying elements may be used to advantage.

STEEL, HEAT TREATMENT OF

Annealing Sheet Steel. The Annealing of Sheet Steel, Francis G. White. Am. Soc. Steel Treating—Trans., vol. 4, no. 2, Aug. 1923, pp. 121–139 and 216–217, 18 figs. Discusses annealing of low-carbon sheet steel from mill standpoint; grain growth caused by slow cooling rate from annealing temperature is shown in photomicrographs; furnace designs, temperature curves, and stamping tests; outline of general practice in one plant.

TOOLS

Hardened, Production of. Tool Room Troubles, A. H. Kingsbury. Am. Soc. Steel Treating—Trans., vol. 4, no. 2, Aug. 1923, pp. 197–215. Review of various factors involved in production of hardened tools; discusses marking of various grades of steel, design, machining strains, heat treating, proper bardening range, quenching speeds, drawing, soft spots and similar troubles, vanadium as alloying element, and grinding practice.

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Mechanical Engineering

The Monthly Journal Published by

The American Society of Mechanical Engineers

Publication Office, 207 Church Street, Easton, Pa. Editorial and Advertising Departments at the Headquarters of the Society, 29 West Thirty-ninth Street, New York

Volume 45 November, 1923 Number 11

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DEPARTMENTAL

ADVERTISING

Price 50 Cents a Copy, $4.00 a year: to Members and Affiliates, 40 cents a Copy, $3.00 a Year. Postage to Canada, 75 Cents Additional; to Foreign Countries $1.50 Additional. Changes of address should be sent to the Society Headquarters.

Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879.
Acceptance for mailiog at special rate of postage provided for io section 1103, Act of October 3, 1917, authorized on January 17, 1921.

J. A. Switzer

Selby Haar

R. H. Lowndes

C. C. Williams

J. W. Roe

W. R. Woolrich

Contributors to This Issue

Major General C. C. Williams, Chief of the Ordnance Department of the U. S. Army, contributes a paper on Ordnance Industrial Mobilization. General Williams was born in 1869 in Nacockee Valley, Ga. He was graduated from the U. S. Military Academy in 1894 and commissioned a second lieutenant in the artillery. In 1898 he was advanced to the rank of first lieutenant of Ordnance and in 1902 to that of captain, then serving for two years as assistant to the chief of Ordnance. From 1907 to 1912 he was a member of the joint Army and Navy Board to formulate specifications for steel forgings. For the next two years he was assistant to the commanding officer at Watertown Arsenal, Mass., and in 1914 was detailed as military observer with the German Army. In 1915 he was commissioned lieutenant colonel in the Ordnance Department and during the following year served on several important boards.

In May, 1917, he was ordered to France as Chief Ordnance Officer of the A.E.F., and in August of that year was commissioned Brigadier General, Ordnance Department, National Army. He returned to Washington in May, 1918, and was acting Chief of Ordnance until July when he was commissioned Major General, Chief of Ordnance. In 1919 General Williams was awarded the Distinguished Service Medal and the decoration of an Officer of the Legion of Honor, France. He was also made a companion of the Order of St. Michael and St. George, Great Britain.

* * * * *

Joseph W. Roe, whose paper on The Measurement of Management is included in this issue, is professor and head of the department of industrial engineering, New York University. Professor Roe was graduated from Sheffield Scientific School, Yale University, in 1895. From that time until 1906 he held respectively the positions of draftsman, chief draftsman, assistant superintendent, designer and engineer with the Winchester Repeating Arms Co., Henry R. Worthington, J. H. Williams & Co., and the Crane Co., when he became instructor and assistant professor in the mechanical engineering department of Sheffield. During the War he served as captain and later as major in the Air Service of the Army. In 1919 he became secretary of the Railway Car Manufacturers' Association and the following year executive engineer of the Pierce-Arrow Motor Car Co., Buffalo, N. Y. In 1921 he became associated with New York University. Professor Roe is president of the Society of Industrial Engineers, chairman of the meetings committee of the A.S.M.E., and a member of the executive board of the American Engineering Council.

* * * * *

J. A. Switzer and W. R. Woolrich, both of whom are on the faculty of the University of Tennessee, are co-authors of the paper on The Water, Coal and Man Power of the Western Slope of the Southern Appalachain Mountains. Professor Switzer was born in 1871 in Brooklyn, N. Y. He was graduated from Cornell University in 1896 with the degree of M.E in E.E. He has taught in the University of Pennsylvania and the Northern Illinois State Normal School. Professor Switzer has had a wide experience in railway construction, irrigation, and sanitary and hydroelectric engineering. Since 1908 he has held the chair of hydraulic and sanitary engineering in the University of Tennessee, also working as a consulting engineer along those same lines.

Professor Woolrich was graduated from the University of Wisconsin in 1911. He completed the student-training course in the Western Electric Co., Chicago, and was assigned to the Deering Works of the Harvester Co. to organize a training course for apprentices. In 1916 he became assistant professor at the University of Tennessee and organized the course in factory management. Three years later he entered into a consulting engineering partnership with W. E. Biggs, while still continuing his relationship with the university but as associate professor of mechanical engineering.

* * * * *

The article on the Chemical Warfare Service published in this issue is based on information supplied to a member of the editorial staff of Mechanical Engineering by the engineers and chemists of the Chemical Warfare Service, War Department, Edgewood Arsenal, Md. The article also includes brief description of apparatus for air analysis which has been contributed by a member of the Edgewood Arsenal staff, Dr. T. B. Hine, Chief, Physical Department, Chemical Division.

* * * * *

Selby Haar, assistant electrical engineer with the Transit Commission of the State of New York and in charge of the engineering section of the Bureau of Equipment and Operation, writes on Modern Subway Cars and Their Operation. Mr. Haar was born in Kansas City, Mo., in 1881. He was graduated in 1904 from the Massachusetts Institute of Technology as an electrical engineer. He completed the testing course of the General Electric Co., Schenectady, N. Y., and then engaged in engineering inspection and design with manufacturing companies, public utilities and railroads. Mr. Haar has been connected with the Transit Commission and its predecessors since 1916.

* * * * *

R. H. Lowndes, author of the article on The Use of Pulverized Coal in Open-Hearth Furnaces, is chief engineer of the Atlantic Steel Co., Atlanta, Ga. Mr. Lowndes was born in South Carolina. He is a graduate of the Georgia School of Technology, class of 1903. For a short period he was with the Telephone Co. in Atlanta and then did some independent mill work, installing machinery. Later he taught for seven years at Georgia Tech. During the War Mr. Lowndes was in charge of the civilian work of a U. S. Army Training School. Afterward he again entered the consulting field where he was engaged until 1921, when he became associated with the Atlantic Steel Co.

A.S.M.E. Annual Meeting, December 3-6

The development of hydroelectric power will be the subject of the leading session at the coming A.S.M.E. Annual Meeting, and the A.S.C.E. and A.I.E.E. are to coöperate in the program for this season. Numerous other sessions have been arranged which will be under the auspices of the Textile, Management, Gas Power, Power, Fuels, Railroad, Ordnance, Aeronautic and Machine-Shop Practice Divisions. The National Exposition of Power and Mechanical Engineering will be held at the Grand Central Palace during the same week.

The final program with announcement of papers and authors will be made in the A.S.M.E. News for November 7.

// MECHANICAL ENGINEERING

Volume 45 November, 1923 No. 11

Ordnance Industrial Mobilization

Under the Supervision of the Assistant Secretary of War

By MAJOR GENERAL C. C. WILLIAMS,[1] WASHINGTON, D. C.

BATTLES and wars are won or lost by *men*. This has been so ever since man first appeared upon the earth, and will continue to be the case until civilization is able to evolve a form of organization which does away with war as a means of settling international disputes.

Weapons used by men are but tools. The nation armed with inferior weapons may be hopelessly handicapped, or a preponderance of numbers may make up for the inferiority if it is not too great. But war is a partizan matter. Our duty is not to prepare for war as a game in which uncertainty of victory will add interest and zest to the conflict. It is to insure that, if war unfortunately comes, the United States will be able to make the most effective use of her resources with the object of securing a successful peace as quickly as practicable. It is axiomatic that our forces should be assured a supply of war matériel *at the minimum equal in quality and amount to that available to a probable enemy.*

Nature of Modern War

Our early ancestors doubtless settled their differences with weapons found at hand. Stones and clubs were readily accessible and there were no questions of "war reserves" and "military procurement." It would be interesting but beside the point to trace the gradual evolution of the military art from its prehistoric beginnings to the present time as influenced by the increasing complexity of available weapons. Suffice it to point out that military art has always been quick to take advantage of every discovery and advance in science and engineering. Conversely, military needs have very frequently forced developments of reciprocal advantage to peace-time pursuits. To wage war effectively today requires the use of enormous quantities of highly complex material. To furnish this material a correspondingly highly organized industrial effort is necessary. Major military efforts now involve not only the military forces of a nation—its army and navy—but require the active coöperation of its entire population and of all its industry.

Dwight F. Davis—Assistant Secretary of War

As Assistant Secretary of War, Mr. Davis is charged with supervision of the procurement of all military supplies and the assurance of adequate provision for the mobilization of industrial organizations essential to war-time needs.

More than ever before, war is an economic problem. The question confronting a nation at war is so to distribute its population and available resources that the war may be most effectively waged and with as little disturbance to the economic life of the country as practicable.

This involves the following main considerations:

1 A decision as to the proportion of the citizenry to be called to the colors and organized as military and naval forces; in short, a military program;

2 Arrangements for providing these forces with food, clothing, and medical care and otherwise supplying their requirements for existence as human beings in a strange environment under severe physical and mental stress;

3 Equipping the fighting forces with the special instruments of warfare—guns, ammunition, tanks, airplanes, gas masks, fire-control equipment, and the multitudinous other special articles which are required in the scientific warfare of today;

4 Maintaining the non-military life and activities of the country during the war as well as circumstances permit.

The first of the above considerations is, for the United States, a matter for decision in the primary instance by the Commander-in-Chief, the President, subject of course to confirmation by Congress, in the form of laws and funds for its support. Naturally a decision of such grave import is never reached without a most careful consideration of all phases of the situation, military, diplomatic, and economic. It is mentioned here because of its double effect on munitions production, i.e., the greater the number of men called to the colors, the *greater* the quantity of arms and ammunition required and the *less* the available working population to produce the requirements. Obviously there must be some proportion between the total population and the total number of the troops mobilized which is best for a particular country under a particular set of conditions.

The second of the considerations named above requires little comment. The individuals who compose an army would likewise require food, clothing, and medical attendance were they civilians. Agencies for furnishing these services exist in time of peace. The main difference in time of war is that inevitably there are increased demands, increased wastage, and poorer facilities for distribution. The ordinary trade channels are to a greater or less extent disorganized, and new machinery must be set up for the supply. Clothing for military use, for instance, will be of a different dye and of military cut. It will be distributed by issue and not through trade channels. All this makes the problem most difficult, but the point which it is desired to make here is that what is required is a diversion and, in many cases, an expansion of facilities already in existence for supplying the peace-time requirements, rather than the establishment of new facilities and the creation of new industries.

Passing over the third consideration for the moment to the fourth, it is obvious that the non-military life and activities of a country must be carried on in war measurably as in peace. Food, shelter, clothing, etc., are as necessary to the civilian population as in peace.

[1] Chief of Ordnance, U. S. Army.

GREETINGS TO THE MEN IN THE INDUSTRIES OF THE UNITED STATES BY THE HONORABLE, THE SECRETARY OF WAR, JOHN W. WEEKS.

No country has made nor is making more determined efforts than ours to remove possible causes for war and to lighten burdens of preparedness.

We now have a system of national defense which enables us to maintain the smallest regular army, in proportion to population, not only among the great powers of Europe but also among the countries of our own continent, excluding Canada, which is protected by its participation in the British Empire.

The essential parts of our new system cannot be neglected.

The National Defense Act of Congress, June 4, 1920, requires the "assurance of adequate provision for the mobilization of materiel and industrial organizations essential to war-time needs."

It is the greatest satisfaction to me to find that the Assistant Secretary of War, who is directing this whole movement, has the patriotic support of the professional men, engineers, manufacturers, and business men of the country.

The accompanying article by the Chief of Ordnance calls for the most serious consideration of all connected with the industries of the Nation.

JOHN W. WEEKS,
Secretary of War.

There will be many changes and curtailments, but the industrial morale is as indispensable to success as that of the fighting men. The "army back of the army" is just as essential to winning a war as the army proper. Then, too, some regard should be paid to the fact that every war must eventually end and that transition from war to peace is in many ways more difficult than that from peace to war. Sight of this fact tends to become lost in time of war. The main thing is, of course, to win the war, and all other things must be subordinated to this.

Industrial Preparedness

Returning to the third consideration mentioned, the primary object of this paper is to discuss the means which are being adopted in time of peace in order that our army may have an adequate supply in time of war of the special instrumentalities of war known collectively as "ordnance."

While man power usually is the deciding factor in war, the tremendous growth in quantity and complexity of war matériel has rendered the supply of this matériel the limiting factor in developing the military effort of our nation—in making our man power effective. Men can be mobilized and trained much more rapidly than they can be provided with munitions of war from new production. It is generally admitted by those who have studied the problem that, on the average, no appreciable quantity of munitions from new production can be delivered to the troops during the first year of a modern war. In other words, the early stages of a war must be fought from reserves accumulated during peace and on hand when war breaks out.

Of course, the supply of instruments of warfare which have no peace-time counterparts is not confined entirely to the Ordnance Deparment. Other supply services, notably the Air Service and the Chemical Warfare Service, likewise have such supply problems. However, the great bulk of such supply for our Army, perhaps ninety per cent of it, falls on the Army Ordnance Department, and the basic method of solution is the same for all services. I shall cover only the question of procurement proper. The equally important problem of distributing the matériel to the army after it has been procured is not here discussed. The importance of the subject lies in the fact, already pointed out, that the supply of munitions is the controlling factor limiting the speed of mobilization.

The procurement activities of the several supply services of the War Department are supervised and coördinated by the Assistant Secretary of War. The duties of the Assistant Secretary in this connection are prescribed by the National Defense Act, as amended on June 4, 1920, as follows:

> Hereafter, in addition to such other duties as may be assigned him by the Secretary of War, the Assistant Secretary of War, under the direction of the Secretary of War, shall be charged with supervision of the procurement of all military supplies and other business of the War Department pertaining thereto and the assurance of adequate provision for the mobilization of matériel and industrial organizations essential to war-time needs.

This simple provision is undoubtedly the most important and far-reaching change in the military policy of the United States since the formation of the General Staff in 1901.

Analysis of the Problem

The first step is necessarily a determination of what is required, in what amounts, and at what times. This depends upon the man power which is to be mobilized and certain factors which are laid down by the War Department. The basic source is the "General Mobilization Plan" of the War Department General Staff, which has the formal approval of the Secretary of War and covers the troops proposed to be used by the United States in the event that it is called upon to exert its "maximum effort." This document is highly confidential. It answers the first of the considerations enumerated above as far as this can be done in time of peace. The organization of these troops is covered by "Tables of Organization," and their equipment by "Tables of Basic Allowances."

If, for example, we wish to know the amounts of 75-mm. high-explosive shell which should be provided for, we can determine from the above sources the number of guns which will probably be consuming these shell in action and in training, month by month, after the emergency arrives. Then, from officially established "Rates of Fire" we can determine the consumptive requirements of the troops for these shell. By making suitable allowances for the time consumed in transporting the matériel to the front, we obtain data as to the amounts which must be delivered from the factories or depots month by month. This may be shown graphically as in Fig. 1. (The data used in this figure and elsewhere in this paper are assumed for the purpose of illustrating the methods and bear no relation to our actual war plans.)

When similar computations have been made for each item of supply, our industrial requirements are definitely known. About 1200 articles of issue are supplied by the Ordnance Department. These embrace about 250,000 components. Knowing our total requirements, the next question which presents itself is, "How are we going to get them?"

Manufacturing Arsenals

The Ordnance Department has six large manufacturing arsenals, namely, Watertown, Frankford, Rock Island, Picatinny, Springfield Armory, and Watervliet, and these are the sources of supply most readily available. They are continuously working at re-

PRESIDENT HARRINGTON PROCLAIMS COÖPERATION OF A.S.M.E. IN INDUSTRIAL-PREPAREDNESS PLAN

The plan of the War Department to keep the nation fit and ready will have the heartiest coöperation of The American Society of Mechanical Engineers. A large standing army provides the means for instant action, tends to make a nation quick to anger and arrogant and aggressive in its relations with others, just as carrying a gun tends to make the individual act violently and without deliberation; but the organization of industry and the making ready of needed plants and of the men responsible for their operation provide the essential industrial support for the more readily organized fighting units and give the nation the calm assurance of strength which makes for deliberation and peace while it discourages aggression on the part of others. The plan of avoiding the belligerent attitude and the economic waste of men and means involved in a standing army, while keeping fit to meet effectively any emergency, is sound and in full accord with American ideals; therefore it merits and has the unreserved patriotic support of our Society and of its individual members.

JOHN LYLE HARRINGTON, President,
The American Society of Mechanical Engineers.

duced strength and can be brought to maximum capacity promptly when the need arises. Their total capacity, however, is relatively small compared with the total requirements under a maximum-effort program. They would be able to produce less than 10 per cent of the required ordnance matériel. Their principal mission is to keep alive in time of peace a knowledge of the art of making ordnance which would otherwise practically vanish. This is a very important function and its value to the United States is incalculable, but the arsenals cannot be depended upon to carry any great portion of the war load.

The District System

The real answer to the question, "How are we going to get them?" lies in the Ordnance District System. Under this system the United States has been subdivided into fourteen Ordnance Districts, as shown in Fig. 2. The object in setting up these districts is to secure decentralized procurement. That such decentralization is essential was shown during the World War. In fact, the districts were first set up by the Ordnance Department during that war and the new arrangement differs from the old chiefly in that the districts are now given greater responsibility and power than before. They are now set up as skeleton organizations to be expanded promptly, in event of need, to full strength.

Each district is in charge of a "district chief." These chiefs have been chosen from among the prominent men of their respective districts. They are men of large affairs who have the support and respect of industry in their districts. While in time of peace it is expected that district chiefs will supervise rather than go into the details of the work, many of them devote a surprisingly large proportion of their time to the affairs of the district. In time of war they would devote their entire time to district activities.

Each district chief has assigned to him in time of peace, as executive assistant, an officer of the regular army, whose entire time is devoted to the work.

The duties of the district offices in time of war will be to procure, produce, and inspect such quantities of ordnance matériel as may be assigned to their respective districts, and each district chief is supreme in his district as far as these functions are concerned. In time of peace they prepare for this work in the manner discussed below.

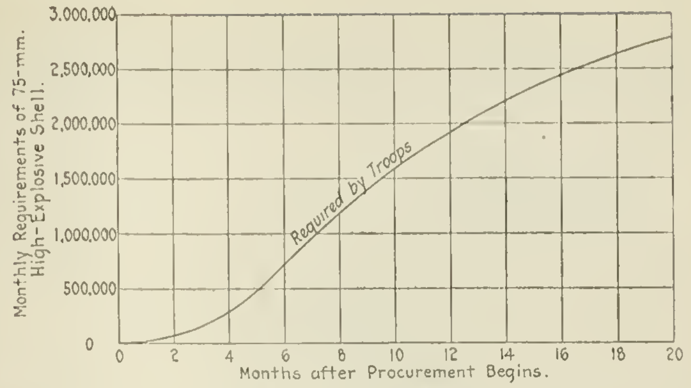


Fig. 1 Chart Showing Amounts of 75-Mm. High-Explosive Shell Which Must Be Delivered from the Factories or Depots Month by Month

The following is a list of district chiefs appointed to date:

District	*Chief*
Baltimore	Howard Bruce
Birmingham	Col. C. L. Harrison
Boston	Col. C. H. Tenney
Bridgeport	Col. B. A. Franklin
Chicago	E. A. Russell
Cincinnati	Col. C. L. Harrison
Cleveland	Col. Bascom Little
Detroit	H. A. O'Dell
New York	Col. John Ross Delafield
Philadelphia	John C. Jones
Pittsburgh	R. M. Dravo
St. Louis	M. E. Singleton
San Francisco	Lt. Col. Bruce Cornwall

The war organization of the Manufacturing Service of the Ordnance Department and the District Offices is shown in Fig. 3. It is to be noted that for each division of the Manufacturing Service

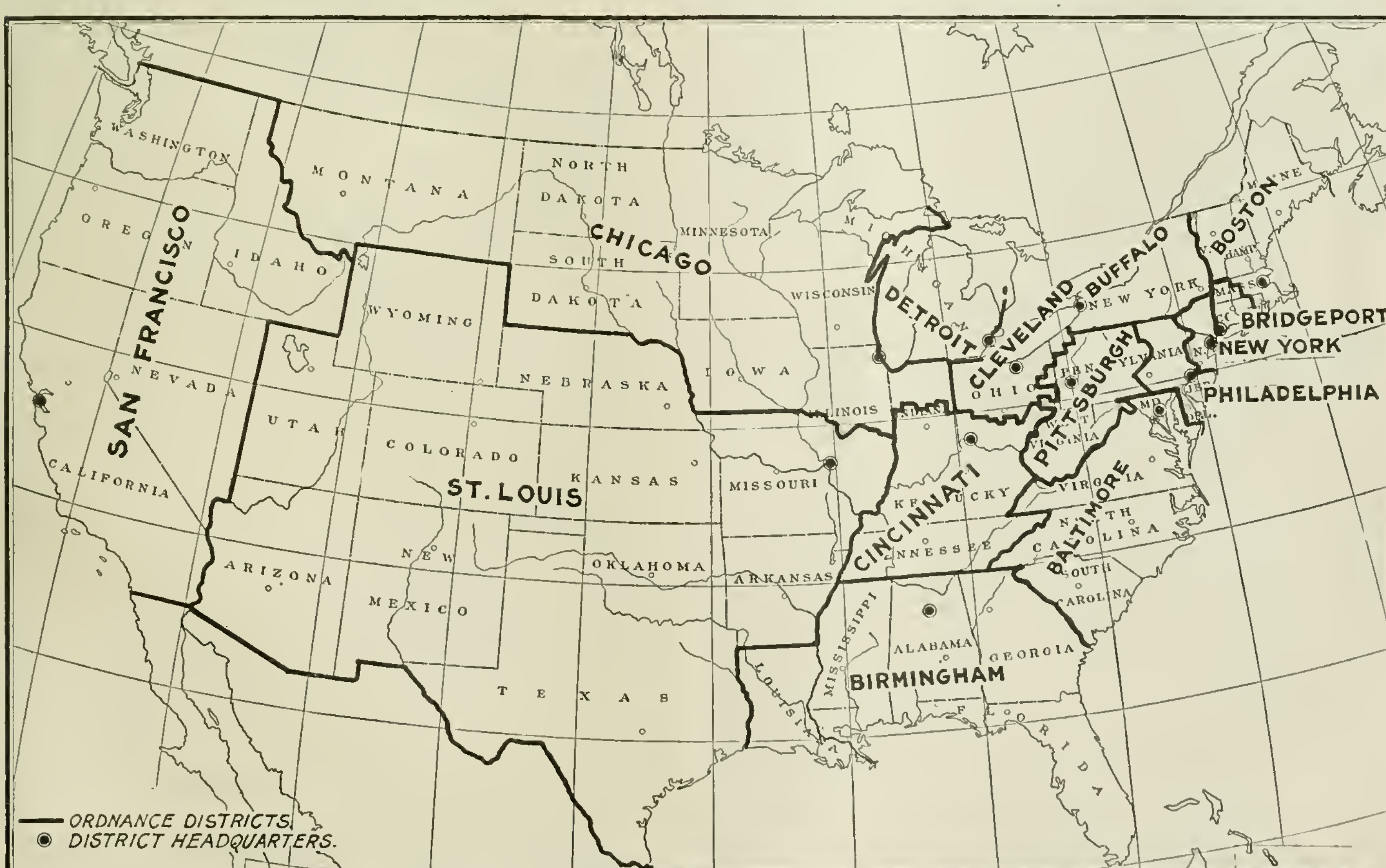


Fig. 2 Map Showing the Fourteen Ordnance Districts into which the United States Is Divided

there is a corresponding division in the District Offices. These divisions are further divided into sections. For instance, the Artillery Division of the Manufacturing Service and the Artillery Divisions of the several District Offices include the following sections:

Cannon Section
Fire-Control Section
Mobile-Gun Section
Railway and Seacoast Section.

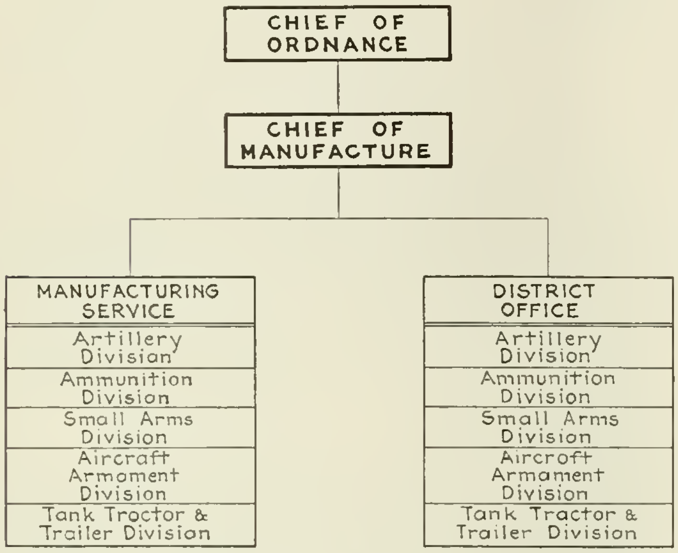


Fig. 3 War Organization of the Manufacturing Service of the Ordnance Department and the District Offices

The object of this parallel organization is to facilitate the transaction of business. A very large portion of all communications between the Ordnance Office and the districts in time of war will involve routine matters or be concerned with minor decisions only and will go direct from the heads of corresponding sections. Only cases involving policy or differences of opinion which cannot be settled in this manner will be referred higher. For instance, a difficulty which the cannon section of the Ordnance Office cannot settle with the cannon section of a particular district may be settled by the heads of the respective artillery divisions, or it may be referred still higher and be decided by the chief of the Manufacturing Service. This official is the first in the chain who has direct *control* over the entire organization. The lines of communication between the sections and divisions are chiefly informative.

Allocation of Orders

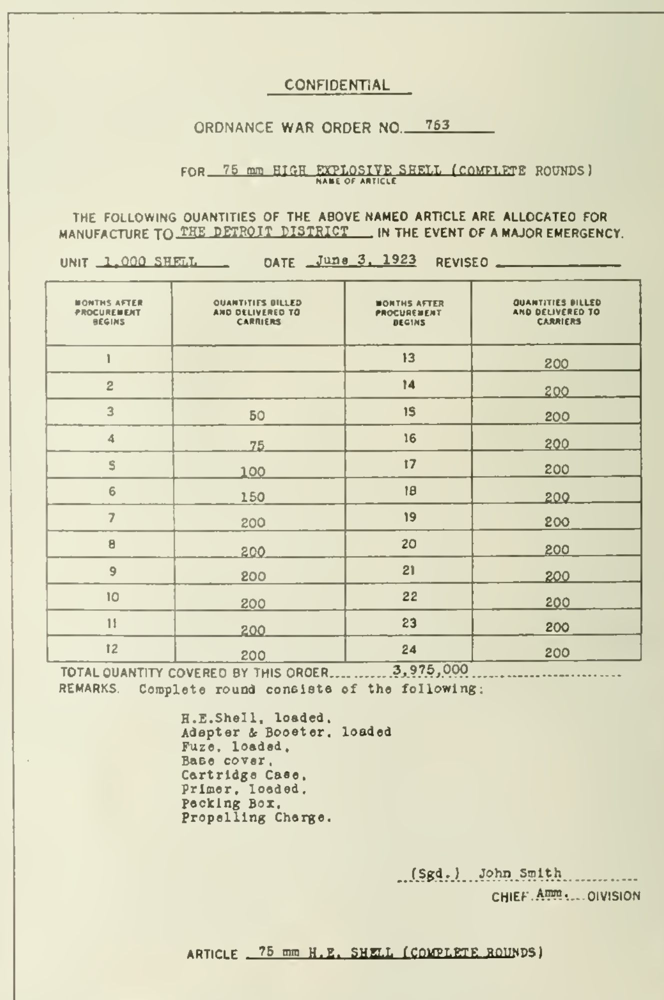
The total requirements for matériel for which the Ordnance Department is responsible having been worked out as indicated above, the next step is to place war orders for the matériel. These orders are being placed at the present time. They will be revised yearly in time of peace and, of course, will be modified continually in time of war. The process of placing them is as follows:

The total requirements for a given article, as for instance the 75-mm. high-explosive shell, are divided between the districts as well as can be determined from existing knowledge of the capacities of the several districts. The amount of each article which it is desired to get from each district is then allocated to that district on the form shown in Fig. 4. This gives complete information as to what is wanted from the districts. The district office investigates the various firms in the district which may be in a position to produce the article and decides upon which are to be given orders for it. These orders are reported to the Ordnance Office on the forms shown in Fig. 5. Any necessary correspondence in relation to placing orders for matériel is conducted directly with the proper division of the Ordnance Office. The sum total of all orders for a given article can, of course, be known from these reports. This will represent the capacity of the country which is to be placed in production for this article in the event of a major emergency.

In order to prevent conflict between the several procuring services, the Assistant Secretary of War allocates the various industrial organizations which may be in a position to accept war orders, in such manner as the best interests of the Government seem to dictate. In this way endless confusion and duplication of effort are prevented and each organization understands exactly what the total demands of the War Department upon it are to be.

Reserves

Requirements are computed on the basis of the needs of the army month by month. The maximum requirements for items which are consumed, such as ammunition, are reached when the army has reached its maximum strength and is completely engaged in the theater of operations. The total production to be reached in the districts is planned accordingly. Naturally, it will take a considerable period for the factories to reach this production. Since troops can be trained more rapidly than munitions can be gotten into production, and it is essential that sufficient troops provided with necessary munitions be available at all times to prevent defeat before the industry of the country can assume its load, the available new production in the early months of the war will inevitably fall below the needs of the troops. A deficit will be incurred as illustrated by Fig. 6. To tide over the period during which new production is insufficient, sufficient reserves must be maintained in storage. From economic reasons these are kept to a minimum both in kind and amount. *However, the maintenance of a proper reserve behind which our industry may be mobilized is an indispensable element of the national defense.* In fact, considering the highly developed state of our manufacturing methods and our great natural resources, it seems fairly certain that no power or combination of powers now in existence could successsfully invade the United States after our man power and our industry had been fully mobilized. From this point of view and from the standpoint of



CONFIDENTIAL

ORDNANCE WAR ORDER NO. 763

FOR 75 mm HIGH EXPLOSIVE SHELL (COMPLETE ROUNDS)
NAME OF ARTICLE

THE FOLLOWING QUANTITIES OF THE ABOVE NAMED ARTICLE ARE ALLOCATED FOR MANUFACTURE TO THE DETROIT DISTRICT IN THE EVENT OF A MAJOR EMERGENCY.

UNIT 1,000 SHELL DATE June 3, 1923 REVISED

MONTHS AFTER PROCUREMENT BEGINS	QUANTITIES BILLED AND DELIVERED TO CARRIERS	MONTHS AFTER PROCUREMENT BEGINS	QUANTITIES BILLED AND DELIVERED TO CARRIERS
1		13	200
2		14	200
3	50	15	200
4	75	16	200
5	100	17	200
6	150	18	200
7	200	19	200
8	200	20	200
9	200	21	200
10	200	22	200
11	200	23	200
12	200	24	200

TOTAL QUANTITY COVERED BY THIS ORDER 3,975,000

REMARKS. Complete round consists of the following:

H.E.Shell, loaded.
Adapter & Booster, loaded
Fuze, loaded,
Base cover,
Cartridge Case,
Primer, loaded,
Packing Box,
Propelling Charge.

(Sgd.) John Smith
CHIEF Amm. DIVISION

ARTICLE 75 mm H.E. SHELL (COMPLETE ROUNDS)

Fig. 4 Form Used in Allocating Quantities of an Article to a Given District for Manufacture

the present economic development of the world, it may be said that *our next major war will be won or lost on the adequacy of our reserves.*

Economy of System

The events of the World War are too fresh in our minds to make it necessary to emphasize the money savings that will result because of an orderly peace-time approach to the problem of placing war orders. There will be no excited competitive bidding for facilities between different branches of the Government; there will be no over-ordering of one article or component with consequent unbalancing of supply. Manufacturers will have opportunity to deal locally with representatives of the Government in time of peace and each will know what he is expected to produce in time of war.

CONFIDENTIAL

REPORT ON PRODUCTION SCHEDULE NO. 498

FOR 75 mm HIGH EXPLOSIVE SHELL (COMPLETE ROUNDS)
NAME OF ARTICLE

DETROIT ORDNANCE DISTRICT

UNIT 1,000 SHELL. DATE Sept. 6, 1923 REVISION

MONTHS AFTER PROCUREMENT BEGINS	DESIGNATION OF PLANT OR FIRM WITH MONTHLY DELIVERIES TO CARRIERS			
	A	B	C	0
1				
2				
3				
4				
5				
6	20	25		
7	30	35		
8	40	50		
9	66	60		
10	70	75		
11	90	100		
12	100	100		
13	100	100		
14	100	100		
15	100	100		
16	100	100		
17	100	100		
18	100	100		
19	100	100		
20	100	100		
21	100	100		
22	100	100		
23	100	100		
24	100	100		

NAMES OF PLANTS OR FIRMS TO BE LISTED BELOW TO CORRESPOND TO LETTERED COLUMNS ABOVE. AFTER NAME OF EACH PLANT OR FIRM STATE WHETHER REFERENCE IS HAD TO THE USE OF "EXISTING FACILITIES" "READILY CONVERTIBLE FACILITIES" OR "NEW FACILITIES" USE TWO OR MORE SHEETS IN CASE MORE THAN FOUR PLANTS ARE REPORTED.

A THE BROWN MANUFACTURING COMPANY - New Facilities
B JONES & SMITH CORPORATION - New Facilities
C
D

ARTICLE 75 mm HIGH EXPLOSIVE SHELLS (COMPLETE ROUNDS)

Fig. 5 Form Used by District Office in Reporting to Ordnance Office the Orders Given for Production

By proper planning the time interval between the beginning of war-procurement negotiations and the delivery of the munitions to the troops will be greatly reduced. Such a time reduction will shorten any modern war since a preponderance of munitions will hasten the end of the war. In money such a curtailment of hostilities may easily mean a saving of a vast amount. Thousands of lives on which a money value cannot be placed will also be preserved to the country.

The outlay in time of peace to secure this condition of preparedness is not excessive. The coöperation of the potential producers is the important consideration. A relatively small amount of coöperation from the many potential producers in this country is rapidly placing the United States in a state of industrial preparedness immeasurably better than ever before in the history of the country.

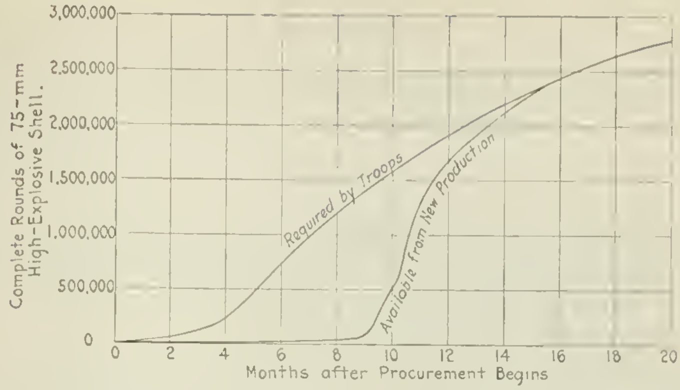


Fig. 6 Chart Showing Insufficiency of New Production of Shell for Troop Requirements and the Necessity of Maintaining Reserves in the Early Months of the War

Conversion of Skoda Works to Peaceful Purposes

The Skoda Works in what is now Czechoslovakia were justly called the Austrian Krupp's. Since the armistice they have been converted to peace-time production with apparently gratifying success both technically and commercially.

Where before and during the war the greatest shops of the company were bristling with long-range guns, dreadnought turrets, and other implements of war, today one sees only the construction and assembling of locomotives, newspaper presses, milk separators, and similar peaceful and productive work in hand.

From the standpoint of economics this fact in itself is a remarkable feat. Before the Treaty of Versailles, the Skoda Werke of Pilsen occupied a position in the dual monarchy not dissimilar to that of Krupp's in Germany. When the war came the Skoda plants were rapidly enlarged and together bore the burden of supplying the Austrian armies with the bulk of their artillery. When the war ended it seemed as if factories like Skoda would be forced to close up shop in part at least, or cast about for ways and means of adapting themselves to the changed conditions of the market.

Czechoslovakia, where the works are now located, is a comparatively small country and would not be capable of supporting such a large plant as the Skoda, which had therefore to go into lines of production where they could count on a wider market. To do this they have bought patents, have experimented along new lines of manufacture, and carefully studied the demands of other countries. They began the manufacture of agricultural machinery, for which it was thought there would be a big market following the war, by buying from the Prager Works of Prague their patent on an 80-hp. heavy motor plow. Tractors and small plows, together with cream separators, were also added to the agricultural program. The war led to unusual depression in most of the factories of the warring countries, so that an increased demand for steam and gas engines and stationary boilers of all kinds was a foregone conclusion.

To replace mining equipment which had been allowed to deteriorate and provide machinery for mining on a wider scale, conveyors and ore separators were added to the list. A pronounced boom in shipping immediately following the war led to the production by the Skoda Works of steam turbines and marine engines for Italy.

Another more important line of development was found in the building of locomotives and railway equipment. No new types of locomotives were demanded, since the Czechoslovak Government, pending the development of electrically run railroads, preferred locomotives of a type which would afford easy interchangeability of parts with old engines which had been left to them under the treaty. Practically the only new type, in fact, which has been built by the Skoda Works since the war is an 83-ton locomotive with a 2-10-0 wheelbase.

In this connection, it should not be forgotten that the Skoda Works, even before 1914, occupied an important position in the industry, in fact a dominating one in certain lines. This was so to such an extent that, for example, the pipe bends installed in the giant turbines at Niagara Falls were turned out in the Skoda factory just before the war.—Henry Obermeyer and Arthur L. Greene in *American Machinist*, vol. 59, no. 14, Oct. 4, 1923, p. 519.

Measurement of Management

The Need of Measurement—Characteristics Necessary in Any Method of Measuring Management—Outline of a Method for Comparing Managerial Performance in Different Plants or Variations Thereof in a Single Plant

By JOSEPH W. ROE,[1] NEW YORK, N. Y.

THE purpose of this paper is to outline the problem and to suggest a method for evaluating management which will be trustworthy, practically useful, and as free as possible from the element of personal opinion.

Is Management Measurable? It is desirable to face this question squarely in view of the frequency with which we encounter one or the other of two answers to it. The first is, "Of course it is, and the balance sheet and profits are the measure." This is too easy to be true. Profits are usually an indication of good management, not a quantitative measure of it. They depend on conditions beyond the control of the management, as well as on those within its control. A business which showed a good profit in 1919, at the height of the boom, may have shown none in 1921, at the depth of the depression; and yet it may have called for more skill to have avoided a receivership in 1921 than to have earned the dividend in 1919. Any true measure must confine itself to those conditions over which management has control.

The other answer is, "No. Skill in management is too complex and too personal to be capable of measurement at all." This is the other extreme. Management must be, and is being, daily evaluated in *some* way, if not by measurement, then by personal judgment. The complexity and personal element are granted. Management, from this very complexity, is partly mechanistic, conforming to natural and sociological laws, and only in part personal. The terms "Science of Management" and "Art of Management" are both in general use. In so far as management is a science, measurement can and should be used, to the great advantage shown in every other science. Those elements which constitute an art, and are based on personal skill, leadership, and imagination, as well as the vital element of integrity, can and should be left to judgment as heretofore. Where applicable, measurement is more trustworthy. It should therefore be applied wherever possible.

What Does Management Cover? Management is recognized to cover a much wider field than formerly. This is reflected in the transactions of the A.S.M.E., which contain the most complete record of its development. The earlier volumes deal only with the technical aspects of production. In 1886 Mr. Towne proposed that the Society undertake to gather information on industrial management. In 1889 he gave his paper on Gain Sharing, and Mr. Halsey's paper on the Premium Plan was given in 1891. In later volumes one sees the range of topics constantly widening. Mr. Taylor's work was, at first, also directed toward finding a satisfactory basis for wage payment, but his investigation steadily broadened until it included a whole system of shop management, cost accounting, routing and scheduling, etc. Today management is generally recognized to include not only production, but finance, purchasing, sales, accounting, and personnel administration.

The methods of measurement proposed in this paper will be confined chiefly to the field of production, although it should be recognized from the start that production is only one of a number of equally important functions. This limitation is made because it seems at present to be the field in which measurement can be most readily applied and with the greatest promise of success. The development of a workable method covering production may make it easier to develop methods for other fields.

The Need of Measurement. The management function has been *judged* since the days of the stone age, when men first began to work collectively. Until recently, however, there has been little thought of actually *measuring* it.

There is a great difference between judgment and measurement. To judge is to arrive at a conclusion or a decision by weighing or comparison. To measure is to ascertain quality, dimensions, or quantity by comparison *with a standard*. In judging things, they are compared one with another. In measuring them, all are compared with the same thing, namely, the standard. Comparison is common to both, but the use of an agreed-upon standard as the basis for comparison distinguishes measurement from judgment. Paintings are judged, pistons are measured. Judgment is the more widely applicable process. Measurement is possible only where a standard can be used. Measurement, where applicable, is the more definite and satisfactory, because all agree to compare with the same thing, the standard.

If practicable standards can be set up for at least some of the managerial functions and suitable methods of comparison also agreed upon, a part at least of the personal element used in evaluating management can be eliminated; and in so far as measurement can be thus substituted for judgment, to that extent will the rating become more trustworthy.

There is increasing need for more trustworthy evaluations of management because of:

- *a* The increasing scale of production. Mistakes in management are more disastrous now than when production was on a smaller scale
- *b* The widening of competition to a national and even international basis. To compete with foreign labor American productive facilities must be used to maximum advantage
- *c* The narrowing margin of profit. In the easy-going days a generation or two ago, profits were large enough to permit inefficiencies of management which today would be fatal
- *d* The development of management as a separate function Formerly the manager was usually the owner. Now, more and more, he is acting for others who are the owners and is responsible to them. It is desirable that the owners have better means for gaging the effectiveness with which their business is being managed, and that the managers be able to prove their work to the owners
- *e* The diversity of the points of view from which management is, and must be, judged. The interests and personal views of those making these judgments lead to different estimates for the same set of conditions. In so far as they can agree upon a common method, it will be a benefit to all
- *f* The rapid development in management methods. New methods are being tried, some wise, some not. We should be able to determine their effectiveness quantitatively, if possible; to pass judgment on them on the basis of actual fact, instead of predisposition, enthusiasm, or habit
- *g* It is desirable to have some form of progressive judgment, to know what the management *is accomplishing*, not what it has done after crucial mistakes have been made.

It is a healthy sign that responsible industrial engineers and executives are the very ones who are most desirous to have their work measured. They are calling for it and will welcome it as a means for assisting them in their work.

The Effect of Measurement in Other Sciences. The great development of modern science has been based upon improvements in measurement. Before the application of measurement the sciences were largely speculative, practically useless, sometimes dangerous, and often a cloak for imposture. With the development of measurement they have grown exact, effective, and useful.

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[1] Professor of Industrial Engineering, New York University. Mem. A.S.M.E.

Presented at the Management Session of the Chattanooga Regional Meeting of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, Chattanooga, Tenn., October 23 and 24, 1923; also October 23 at joint management meeting of New York Sections of THE AMERICAN SOCIETY OF MECHANICAL ENGINEERS, The Taylor Society, the Society of Industrial Engineers, the National Association of Cost Accountants, and the American Management Association.

Natural philosophy has become physics, alchemy has become chemistry, astrology has become astronomy, and modern medicine and surgery have developed from the blood letter and chirurgeon of the Middle Ages.[1]

There is every reason to believe that in so far as measurement can be applied to management, it will be of similar benefit. Measurement in management should

a Increase its practical utility

b Permit action with more practicable results, and

c Tend to sift the wheat from the chaff both in men and methods.

Use of Proven Methods. The answer to a new problem often comes through the application of methods and means which have been in successful use in other fields. We now have satisfactory means for measuring the performance of machines and of workmen in connection with commercial production, which are in daily use and of incalculable value in modern production. It is well to consider how far these may be applicable in the field of management.

Measurement in Engineering

Three elements are characteristic of measurement as applied to commercial production:

a An agreed-upon standard, the qualities of which we seek to approach or duplicate

b Agreed-upon units of measurement applicable both to the standard and to the things to be measured

c Means or methods of *impersonal* comparison of the thing to be measured with the standard by means of the agreed-upon units. Impersonality is the soul of measurement and is one of the elements which differentiate it from judgment. Different persons, properly qualified and in possession of the same facts, should be able substantially to duplicate the results.

As an embodiment of these three characteristics, we might have

As the standard (*a*), the barrel of a model rifle

As units of measurement (*b*), inches, degrees of curvature, hardness, etc. These can be used to express the desired qualities so completely that 10,000 barrels can be made from well-dimensioned drawings without the use of the model barrel

As methods of impersonal comparison (*c*), plug and ring gages, contour gages, etc., whereby any properly qualified person can determine the conformity of the production barrels to the model within the limits desired.

Phases Affecting the Problem. The use of these elements in actual production is scientifically correct and perfectly practical. They are used in the production of millions of dollars worth of material every day. It is worth while to see if their use cannot be extended from the material side of production to the more intangible executive side. In doing so, however, three phases should be borne in mind.

(*a*) *Break-Up into Functions.* It is a fundamental principle in science and engineering that a problem involving several variables can be solved only by segregating each variable, solving it separately, and then combining the results. Babbage recognized this as applying with equal force to problems of manufacture in his remarkable "Economy of Manufactures," written nearly 100 years ago. Management is a complex function involving a large number of variables and no satisfactory rating for it can be obtained unless this procedure is followed. This breaking down into separate elements was the basis upon which Mr. Taylor built up his methods of time study. The only hope for measuring management successfully is to extend his general method from the study of a single task to that of management as a whole.

(*b*) *Measurement by Reactions.* Science and engineering continually deal with quantities not directly measurable upon the principle that action and reaction are equal. If we can identify a cause and its effect, and can measure that effect, we have a measure of the cause of that effect. This principle may be utilized in this problem in evaluating some of the executive elements which are not themselves directly measurable.

(*c*) *Extreme Accuracy Not Essential.* Measurement does not have to be extremely accurate to be useful. If we measure in the same way each time, with the same units, and recognize that the results are approximate, we are far better off than with no measure at all.

Characteristics Necessary in Any Method of Measuring Management

Any method of measuring management which has any hope of being successful must have the following characteristics, some of which have already been referred to:

a It must be sound, clear, and convincing

b It must be based on ascertainable facts

c It must reflect the conditions under which the management operates

d It must attempt to measure only such elements as are measurable

e It must be confined to those elements over which the management has control

f It must eliminate, as far as possible, the element of opinion in application, that is, be impersonal

g It must offer a better and sounder basis for measuring the managerial function than we now have

h It must be useful. It should give more than an overall efficiency, and should indicate, if possible, the relative strength and weakness of the various elements to serve as a guide for development and improvement

i It must be as simple as is consistent with the complexity of the problem to be solved.

The author feels that the various methods suggested up to this time fail in one or more of the characteristics given above.

The general procedure used in scientific and engineering measurement can be adapted to the measurement of some, at least, of the elements of management in a way which will satisfy these conditions.

With the above considerations in mind the following method is suggested:

a Break down the managerial function into component elements which may be considered separately

b Set up an ideal performance for each element

c Set up a standard of performance for each element which shall, if possible, conform to this ideal; if this is not possible, one which will give a practical working basis approaching that ideal and will mean the same thing to all. If *no* standard seems practicable at this time, this element may be omitted from the rating

d Set up a method of rating the performance of the management against each of these standards

e Develop a method of bringing together the individual element ratings, properly weighted, into a composite rating.

The final rating should be used with the understanding that it covers only those elements at present considered measurable and that the remaining elements, if any, which do not lend themselves to measurement are still to be evaluated on the basis of judgment as heretofore.

The application of the method which follows is given as illustrating a method of procedure. A more satisfactory division into elements is quite possible. The same is true for the standards and rating ratios set up. These can be established best by those familiar with the conditions in each industry. It is the method only which is emphasized. It will be confined to the field of production, because it is difficult at this time to set up satisfactory standards of performance and methods of ratings in the other fields. Progress is being made in this direction, however, and it is possible that standards and methods for measuring these elements will be developed. The method of analyzing financial statements given in the pamphlet issued by the Robert Morris Associates[1] is a step in this direction. The general financial statement is analyzed into eight ratios. These are weighted in accordance with the conditions of that industry, and brought together into a single rating based on unity. This approaches very closely the procedure set forth in this paper.

[1] Medicine is the least exact and certain of the sciences mentioned just because it is the one in which measurement is most difficult.

[1] "Financial Statements"—An explanation in brief of a system for analysis from the standpoint of the credit grantor and the business executive. Issued by the Robert Morris Associates, Lansdowne, Pa.

Division into Elements. For our present purposes production will be divided into the following elements:

a Purchasing
b Stores Inventory
c Efficiency of Plant, Equipment, and Methods
d Efficiency with respect to Materials Used
e Efficiency with respect to Payroll
f Idleness of Equipment
g Quality of Output
h Keeping of Promises
i Labor Turnover
j Cost Accounting and Records.

With each of these elements we will consider first the ideal performance in respect to this element; second, a practical standard for it, if one is possible; third, a rating ratio for measuring the performance against this standard.

Purchasing

Ideal.

a The securing of the right amount of material, of the right kind and quality
b At the lowest prices available, and
c Having this material on hand when it is wanted, where it is wanted, and in the condition wanted.

Practical Standard. The "right amount" is the least which will provide an uninterrupted supply for production and will maintain the minimum stores required for safe operation. If the proper minimum of the stores of the right kind and in the right condition is maintained at all times, there should be no interruptions of production from failure of raw-material supply. Items (*a*) and (*c*) above will be cared for under the element of Stores Inventory.

The "lowest prices *available*," item (*b*), are not readily ascertainable, and with long-time purchases are complicated by the cost of carrying charges. Current market prices are, however, usually obtainable and may be used in setting up a practicable working standard. Furthermore, in most manufacturing industries the bulk of the value of the total purchases is concentrated in a few basic raw materials.

If we could set up a ratio between the actual cost of these few basic materials used each day and their cost if bought "over the counter" at the market price that morning, we would have a fairly good measure of the purchasing efficiency for these materials. If the actual purchase cost were less than the current market, it would, when divided into the market cost, show a purchasing efficiency above par. If it were the same, the purchasing efficiency would be at par. If the purchase cost is greater, the ratio will be less than unity and the purchasing is below par. If this ratio is favorable for the basic materials, the multitudinous minor supplies which make up the relatively small balance may be disregarded.

Rating Ratio. It would be impractical to make this comparison on a daily basis, and comparison with the monthly average market prices would, in most cases, be sufficient. A practical rating for the purchasing function therefore may be expressed as follows:

$$\text{Rating ratio} = \frac{M_1 + M_2 + M_3, \text{ etc.}}{C_1 + C_2 + C_3, \text{ etc.}}$$

where

M_1, M_2, etc., are the products of the monthly consumption of a selected basic material multiplied by the *average market price* for that material during that month, and

C_1, C_2, etc., are the actual *costs* of these materials *as purchased*.

As pointed out above, if the materials have been purchased at low prices the values in the denominator will be less than the corresponding ones in the numerator. If desired, the ratio for each material may be taken separately, these added, and the sum divided by the number of materials to bring the result to a unit basis. Where the material has been carried a long time, interest and carrying charges may be added to the purchase cost, if that refinement is deemed necessary. Both numerator and denominator are in dollars and the quotient is a ratio for that month which may be less than, equal to, or greater than unity, according as the given materials have been bought above, at, or below the average market prices for that month.

The rating of the purchasing element may be based on the running average of the ratios for the past twelve months instead of a single monthly ratio. Such an average would be fairer than a single ratio, as it will show how well the purchasing department is anticipating prices.

Stores Inventory

Ideal. The maintenance at all times of the lowest amount consistent with having all the material ready for process, when, where, and in the condition needed.

Practical Standard. For simplification, instead of considering all the stores, the same basic raw materials may be used for this element as in the case of purchasing.

Set up for each basic material the minimum safe time which should be allowed to order and obtain that material, with due consideration to distance, reliability of source, contingencies, etc., in accordance with the present well-established practice. These times may, and probably will be, different for each material, and may vary with market conditions.

If three months, for instance, was the safe time allowance on, say, January 1 for obtaining one of these materials, then the sum of the consumptions during January, February, and March is the amount of stores which should have been on hand at that date. This can be used as a standard, and can be divided into the actual stores of the material on hand at that time. This will give a ratio which will be less than, equal to, or greater than unity according as the stores actually on hand were less than, equal to, or more than the safe amount needed. A similar ratio may be set up for each of the basic materials. A moving average for, say, one year of the deviation of the percentages from unity for each material, *disregarding the sign*, i.e., whether the deviation is above or below unity,[1] will indicate how close the stores inventory on that material had been kept to the desirable minimum.

To obtain the ratio for the stores inventory as it stands at the *present* time it is necessary to use the estimated requirements, through the production or sales schedules, as this is the best information we have.

Rating Ratio. The rating ratio can be obtained from the average of the moving averages for the various materials, again disregarding the sign, i.e., whether the deviation is above or below unity. This average deviation should always be *deducted* from unity to obtain the rating.

Unity in this rating would indicate that the management had uniformly maintained the stores inventories of its basic materials at the minimum which had been established as good practice and under the conditions of operation. Ratings less than unity would indicate how far the inventory had been departing from this standard. Examination of the monthly figures would show when, in which materials, and in which directions the deviations had occurred.

For the detail planning and follow-up of the material stores we have in the Gantt layout and progress charts a useful and tried-out method which in itself is an excellent measure of the performance of this function. It does not, however, head up into a single rating as the method suggested does, but can readily be used in connection with it.

Effectiveness of Production

Ideal. The production of the greatest value of salable output with the least expenditure for plant, materials, and labor.[2]

This has three aspects. Production efficiency with respect to

a Plant, equipment, and methods
b Materials
c Labor employed.

A management may be making poor use of a good plant and equipment, or the best possible use of a poor equipment. It is desirable, therefore, to measure these phases separately. This can be done roughly by dividing the product sold per annum in case (*a*) by the plant investment, in case (*b*) by the materials

[1] If the signs of the deviation are not disregarded, plus and minus deviations would offset each other and tend to show conformity to the required quantities when such conformity did not exist. If the deviations are averaged arithmetically without regard to whether they are above or below, we will get a true measure of the conformity.

[2] With respect to labor this should be construed as the least expenditure consistent with sound social conditions, to exclude child labor, etc.

purchased annually, and in case (c) by the total annual payroll. The products *sold* is in general a better value to use than the value of the goods produced, because it represents goods which actually contributed to the income. In certain businesses, such as heavy machinery or shipbuilding, however, the goods produced, including even those only partly finished, may be the better value to use.

Practical Standard. These ratios will of course vary with different industries, and it is necessary to compare them with some standard before we can know whether they are high or low. The most practical standard seems to be the similar ratio for the industry as a whole. Various Government reports such as the 1919 Census of Manufactures and the Statistical Abstract of the U. S. give the capital invested, value of the products, value of the materials used, and total payroll for many industries.[1] There are other sources also, such as trade associations, so that in most cases the information necessary for the comparison is available.

Rating Ratios. If the ratios for the industry are available the rating for efficiency with respect to plant, equipment, and methods would be

$$\frac{\text{Annual sales in dollars}}{\text{Plant investment in dollars}} \div \frac{\text{Total annual output of the industry}}{\text{Total investment in the industry}}$$

The result will be above, equal to, or less than unity according as the ratio for the firm in question is better, equal to, or worse than the average of its competitors. In times of extreme depression it may be fairer to divide this ratio by the idleness ratio, given later under Idleness of Equipment.

The rating with respect to materials would be

$$\frac{\text{Annual sales in dollars}}{\text{Total annual purchase of materials}} \div \frac{\text{Total annual output of the industry}}{\text{Value of raw materials used in industry per annum}}$$

Similarly, the rating with respect to use of labor would be

$$\frac{\text{Annual sales in dollars}}{\text{Total annual payroll in dollars}} \div \frac{\text{Total annual output of the industry}}{\text{Total annual payroll of the industry}}$$

These ratios may be above unity and will show ratings on the basis of the average for that industry or the average of the competition which the firm has to meet.

The material turnover would also be a useful element to measure, but no standards or methods of rating seem to be available. If these could be satisfactorily set up it would be desirable to include it.

Idleness of Equipment

The degree of approach of the actual output to the full capacity of the plant is a significant means for measuring management. In reality it is included in the plant-efficiency ratio above, but it shows directly what use is being made of the equipment and is so easily obtained and is so useful that it is well to set it up separately. Mr. Gantt told the author that he used it continually in diagnosing the situation in a plant.

Ideal. The ideal would of course be to have all the equipment at work at full capacity all the time. Of course, also, this is impossible.

Standard. The same, i.e., 100 per cent or the full capacity of the plant.

Rating Ratio. This would be

$$\frac{\text{Actual production machine hours}}{\text{Machine hours' capacity of the plant}}$$

For each industry the ratio would have a characteristic maximum, always less than unity.

Quality

Ideal. That all goods produced pass all inspections, both producer's and customer's.

Standard. The same, i.e., 100 per cent of the goods produced.

Rating Ratio. This would be

$$\frac{\text{Goods produced which pass all inspections}}{\text{Total goods produced}}$$

This rating will presumably always be less than unity, and it may be in certain cases, as in some garment industries, that a moderate proportion of "seconds" is preferable to the expense of trying for perfection.

Promises

Ideal. All promises kept.

Standard. The same.

Rating Ratio.

$$\text{Rating ratio} = \frac{\text{Number of promises kept}}{\text{Number of promises made}}$$

This rating also will, in general, be less than unity.

Labor Turnover

Ideal. That turnover, only, which is due to inevitable causes, such as death, superannuation, marriage; seldom, if ever, attainable.

Standard. The turnover prevailing in that trade and locality, so far as these can be determined.

Rating Ratio.

$$\text{Rating ratio} = \frac{\text{Turnover of plant under consideration}}{\text{Turnover of that trade and locality}}$$

Cost Accounting and Records

Ideal. The gathering and maintaining of information on all costs which shall be

- *a* Accurate
- *b* Prompt
- *c* Useful, *and used*
- *d* Tied in with the production and financial accounts.

This element is vital in modern management. The author has been unable to discover a standard or means of *measuring* performance in it which would be satisfactory or generally applicable. The best way would be to recognize this frankly; to set up an ideal, and to rate the performance of the management in this element on the basis of judgment of men properly qualified to pass on it.

The Final Rating

The element ratings may be brought together into a final rating as follows:

(1) Element	(2) Individual rating of element	(3) Percentage weight of element in total rating	(4) Weighted rating of element (col. 2 × col. 3)
a Purchasing	....	....	....
b Stores Inventory	....	....	....
c Efficiency of Plant, Equipment, and Methods	....	....	....
d Efficiency with Respect to Materials Used	....	....	....
e Efficiency with Respect to Payroll	....	....	....
f Idleness of Equipment	....	....	....
g Quality of Output	....	....	....
h Keeping of Promises	....	....	....
i Labor Turnover	....	....	....
j Cost Accounting and Records (on basis of judgment)	....	....	....
		100%	
Final Rating	....		....

The separate elements and their ratings as obtained above may be listed as in columns 1 and 2. Percentage weights for each element, suitable for that industry, are set up in column 3; and the weighted value for each element (column 2 × column 3) is extended in column 4. The final or combined rating will be the sum of the items in column 4. Values above unity in the element ratings for *a*, *c*, *d*, *e*, and *i* would indicate that the quality of the management, in these elements, was better than the average of the industry; values below, that it was poorer.

The ratings in column 2 are founded on ascertainable facts and are largely free from opinion or judgment. The weights in column 3 assigned to the various elements, however, must involve judg-

[1] Appendix 2 gives this data for certain selected industries. The Statistical Abstract of the U. S. gives it for more than 300 industries, in addition to those listed in the appendix.

ment, which will of course affect the weighted ratings in column 4. If this is objected to, the use of the method can stop with column 2. A periodic comparison of the variations in the element ratings in that column will, alone, have value in guiding management policies. If our purpose is to measure the management as a whole we must recognize that the elements will have different relative importance in different industries, and they must be weighted to reflect the conditions for each industry. After all, as we have said, extreme accuracy is not required. If some weighting can be *agreed upon* for the industry in question, and all concerned will use that weighting, then column 4 and the Final Rating will have value as a basis for comparison.

Utility of the Above Method

The method outlined furnishes a basis for comparing managerial performance in different plants of the same or allied industries, but more particularly it offers a means of following variations in the management of a single plant.

The element ratings and the final rating may or may not have considerable significance where applied once to a specific business, as of a certain date. If, however, the method be used repeatedly, in the same way, each successive set of ratings will become more trustworthy and useful because we have set up a uniform and orderly basis of comparison for the measurable elements of the executive function.

APPENDIX NO. 1

A PARTIAL BIBLIOGRAPHY ON THE MEASUREMENT OF MANAGEMENT

Gantt, H. L. Measuring Efficiency. Paper No. 1444, Trans. A.S.M.E. vol. 36, p. 417, 1914.

Gantt, H. L. Productive Capacity a Measure of Value of an Industrial Property. Paper No. 1578, Trans. A.S.M.E., vol. 38, p. 1303, 1916.

Shelton, H. W. Mutual Rating. *Bulletin of the Taylor Society.* August, 1920.

Committee Report. Waste in Industry. Report of Special Committee of the Federated American Engineering Societies. McGraw-Hill Co., N. Y., 1921.

Committee Report. Report of the Special Committee to Make a Preliminary Study into Units and Methods of Measurement of the Management Function. Paper before Management Session of A.S.M.E. Meeting, Dec., 1921.

Morrow, L. C. The Bedaux Principle of Human Power Measurement. *American Machinist.* Feb. 16, 1922, p. 241; Aug. 17, 1922, p. 249, and p. 294, Aug. 24, 1922.

(Continued on page 669)

APPENDIX NO. 2

INFORMATION ON CERTAIN INDUSTRIES FOR THE CALENDAR YEAR 1919

Note.—The industries given below are selected out of more than 350 listed in Table No. 160, p. 226, of the Statistical Abstract of the U. S., 1921, from which columns 1 to 5 are taken. The ratios given should be used with caution as the year 1919 was one of abnormal production. The table brings out clearly, however, how widely the ratios vary as between different industries.

1	2	3	4	5	6	7	8
					Ratios of Value of Annual Output to		
Industry	Capital, Dollars	Wages, Dollars	Cost of materials, Dollars	Value of products, Dollars	Capital	Wages	Cost of Matls.
Agricultural implements	366,962,052	66,704,434	144,571,943	304,961,265	0.83	4.57	2.11
Automobile bodies and parts	470,497,552	178,955,503	362,027,302	692,170,692	1.47	3.87	1.91
Automobiles	1,310,451,400	312,165,870	1,578,651,574	2,387,903,287	1.82	7.65	1.51
Boots and shoes, not including rubber boots and shoes	612,625,075	210,734,610	715,269,315	1,155,041,436	1.88	5.48	1.62
Boots and shoes, rubber	131,513,436	30,882,722	50,346,880	116,917,434	0.89	3.78	2.32
Brass, bronze, and copper products	325,299,738	94,132,118	304,823,580	482,312,790	1.48	5.13	1.58
Bread and other bakery products	529,265,779	158,237,059	713,239,411	1,151,896,318	2.18	7.29	1.62
Brick and tile, terra cotta, and fire clay products	355,848,355	78,256,085	67,488,113	208,422,920	0.59	2.67	3.10
Butter	162,302,108	19,052,729	514,345,739	583,161,011	3.60	30.60	1.13
Canning and preserving, fruits and vegetables	223,692,234	43,592,537	265,628,525	402,242,972	1.80	9.23	1.52
Cars and general shop construction and repairs by steam-railroad companies	694,286,410	687,617,312	515,803,210	1,279,235,393	1.84	1.86	2.48
Cars, steam-railroad, not including operations of railroad companies	335,207,363	78,284,647	356,084,545	538,222,831	1.61	6.88	1.52
Cement	271,269,259	33,194,920	79,509,800	175,264,910	0.65	5.29	2.21
Chemicals	484,488,412	72,848,324	216,301,279	438,658,869	0.91	6.02	2.03
Clothing, men's	554,147,279	197,821,990	605,752,176	1,162,985,633	2.10	5.90	1.92
Clothing, women's	390,526,517	195,295,834	680,406,844	1,208,543,128	3.09	6.19	1.77
Coke, not including gas-house coke	365,249,622	42,299,292	224,266,673	316,515,838	0.87	7.49	1.41
Confectionery and ice cream	317,043,923	76,159,866	368,809,170	637,209,168	2.01	8.37	1.72
Cotton goods	1,853,099,816	355,474,937	1,277,785,597	2,125,272,193	1.15	5.98	1.66
Dyeing and finishing textiles, exclusive of that done in textile mills	299,948,486	57,189,978	174,742,815	323,967,683	1.41	5.66	1.85
Electrical machinery, apparatus, and supplies	857,855,496	238,188,852	425,098,211	997,968,119	1.16	4.20	2.34
Engines, steam, gas, and water	454,124,733	105,435,455	217,550,771	464,774,735	1.02	4.41	2.14
Explosives	133,247,684	12,504,986	45,911,049	92,474,813	0.69	7.40	2.01
Flour-mill and grist-mill products	801,624,507	50,888,383	1,799,180,987	2,052,434,385	2.56	40.40	1.14
Food preparations, not elsewhere specified	245,282,687	29,392,209	494,597,157	631,598,150	2.58	21.50	1.28
Foundry and machine-shop products	2,104,980,938	622,571,129	948,069,381	2,289,250,859	1.09	3.68	2.41
Furniture	423,992,405	141,116,316	261,523,395	571,356,333	1.35	4.05	2.18
Gas, illuminating and heating	1,465,656,265	52,758,628	157,550,882	329,278,908	0.22	6.24	2.09
Hardware	133,925,619	45,229,950	58,533,769	154,524,888	1.15	3.42	2.64
Ice, manufactured	270,725,786	34,001,837	42,877,509	137,004,798	0.51	4.03	3.20
Iron and steel, blast furnaces	802,416,541	73,769,395	621,286,496	794,466,558	0.99	10.80	1.28
Iron and steel, steel works and rolling mills	2,656,518,417	637,637,430	1,680,575,758	2,828,902,876	1.06	4.44	1.68
Knit goods	516,457,991	125,199,820	427,095,560	713,139,689	1.38	5.69	1.67
Leather, tanned, curried, and finished	671,341,553	88,205,473	646,521,527	928,591,701	1.38	10.51	1.44
Lumber and timber products	1,357,991,571	489,419,091	470,960,488	1,387,471,413	1.02	2.84	2.95
Lumber, planing-mill products, not including planing mills connected with sawmills	361,848,079	91,976,526	299,265,652	500,438,258	1.38	5.45	1.67
Machine tools	231,039,843	66,178,969	59,034,308	212,400,158	0.92	3.21	3.59
Oil and cake, cottonseed	203,457,371	20,615,193	495,192,294	581,244,798	2.86	28.20	1.17
Paints	177,314,815	19,550,371	165,604,116	256,714,379	1.45	13.12	1.55
Paper and wood pulp	905,794,583	135,690,642	467,482,637	788,059,377	0.87	5.82	1.69
Petroleum refining	1,170,278,189	89,749,637	1,247,908,355	1,632,532,766	1.39	18.20	1.31
Prio ing and publishing, book and job	446,554,984	141,476,243	211,067,174	597,663,228	1.34	4.23	2.83
Printing and publishing, newspapers and periodicals	614,045,344	144,348,173	300,385,187	924,152,878	1.51	6.40	3.15
Rubber tires, tubes, and rubber goods, not elsewhere specified	782,637,722	156,806,828	525,686,309	987,088,045	1.26	6.29	1.87
Shipbuilding steel	1,268,640,254	538,372,576	643,752,814	1,456,489,516	1.15	2.70	2.26
Shirts	102,012,047	25,833,855	127,087,745	205,327,133	2.01	7.95	1.62
Silk goods	532,732,163	108,226,330	388,469,022	688,469,523	1.29	6.36	1.77
Slaughtering and meat packing	1,176,483,643	209,489,263	3,782,929,533	4,246,290,614	3.61	20.30	1.12
Smelting and refining, copper	308,680,268	25,723,371	584,410,173	651,101,591	2.11	25.30	1.12
Soap	212,416,866	21,228,063	238,518,858	316,740,115	1.49	14.90	1.33
Tobacco, cigars, and cigarettes	416,395,472	111,313,348	353,297,366	773,662,495	1.86	6.95	2.19
Tools, not elsewhere specified	134,731,947	43,836,069	45,796,967	144,201,668	1.07	3.29	3.15
Steam fitting and steam and hot-water heating apparatus	133,097,464	45,742,525	72,016,393	160,285,488	1.20	3.50	2.22
Stoves and hot-air furnaces	122,813,373	41,321,133	54,803,316	145,717,963	1.19	3.53	2.66
Structural ironwork, not made in steelworks or rolling mills	219,470,095	59,920,132	168,800,715	294,962,419	1.34	4.92	1.75
Sugar, beet	224,584,679	15,908,118	87,029,144	149,155,892	0.67	9.40	1.71
Sugar refining, not including beet sugar	193,540,825	22,710,464	662,143,981	730,986,706	3.79	32.19	1.11
Wire	102,016,777	29,289,667	102,813,591	162,151,236	1.59	5.55	1.58
Woolen and worsted goods	831,694,748	168,108,681	665,594,683	1,065,434,072	1.28	6.34	1.60

The Water, Coal, and Man Power of the Western Slope of the Southern Appalachian Mountains

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THE purpose of this paper is to correlate our present knowledge of the water powers of the western slope of the Southern Appalachian Mountains with the coal resources and with the labor resources of the region. At a recent meeting of the Southern Appalachian Power Conference, Mr. Frank G. Baum, of California, calmly said that within a period of 20 years all of the water power of the United States will have been developed. This seems a super-bold prediction; yet if a curve of growth of the hydroelectric industry be plotted, it is not difficult to so project the curve beyond the present as to justify such a prediction. Mr. Baum's dream of a single superpower system, covering the United States like a benign blanket, is daily being wrought into reality—and before we know it, the thing will be done! However this may be, the isolated steam plant is already superannuated and will soon be superseded. The future of steam power is intertwined with water power, and our interest in it now is to find the most strategic locations for the placing of large base-load plants.

However, absorbing and essential as are considerations of cheap power, whether derived from water or from steam, the matter of greater importance to industry is man power, that is to say, the labor supply.

During the World War we came to realize that the congested district centering around New York was somewhat overindustrialized. If this section is to maintain its past rate of industrial growth, dependence must be placed upon immigrant labor. Because of vested interests, human inertia, and the provincial outlook of those whose knowledge of America does not extend beyond the metropolitan district, no sudden decline need be looked for in this industrial beehive.

The western slopes of the Southern Appalachian mountain chain possess advantages to industry not yet fully appreciated except, perhaps, in limited circles. Altitudes lifting the country above the general level modify the climate which the latitude alone would determine. Yet the latitude does insure a mildness of climate which liberates life from the rigors of the North. The abundant rainfall characteristic of the region results in a regimentation of stream flow which to northern hydroelectric engineers is a never-ending source of amazement. Not only does the resulting high annual rate of run-off surprise them, but as well the high summer rates of flow and the absence of the excessive winter and spring floods to which their experience on northern streams has accustomed them.

An abundance of coal of high quality, and in many places the availability of adequate condensing water at naturally low tem-

Fig. 1 Map of the Southern Appalachian Region Showing the Transmission Systems Thus Far Built

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Presented at the Chattanooga Regional Meeting of the Southern Local Sections of The American Society of Mechanical Engineers, Chattanooga, Tenn., October 23 and 24, 1923.

peratures, are factors. And finally here is found a population more purely of Anglo-Saxon strain than can be found elsewhere in the country. The combination of these factors is a matter of more than local interest. It is the purpose of this paper to merely touch lightly upon this theme.

The Present Status of the Power Industry

Fig. 1 is a map showing the transmission systems of the Southern Appalachian region as built to date. In 1905 the nucleus for future growth was planted by the Southern Power Co., which in that year built the first mile of high-tension transmission line in this region. During the years from 1905 to 1912 the system slowly spread over the Piedmont Plateau, or that portion of it occupied by the Southern Power Co.

In the year 1912 the Watauga Power Co. built 17 miles of transmission line and delivered Watauga River power to the City of Bristol. Within a few days of the opening of this line, the Tennessee Power Co. (now the Tennessee Electric Power Co.) began to furnish power to Knoxville and to Chattanooga from the Ocoee River. Later in the year the Georgia Railway & Power Co. opened the turbine gates at Tallulah Falls and the power of the Tallulah River flowed into Atlanta.

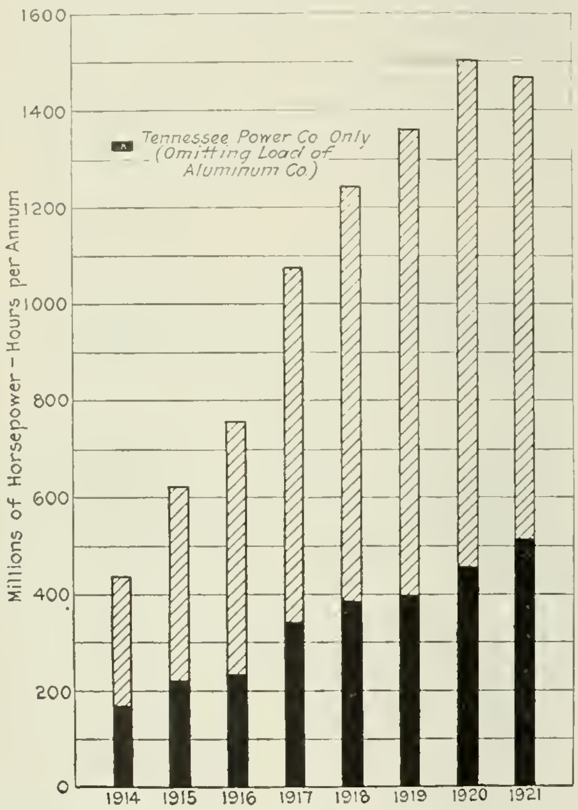


Fig. 2 Combined Power Output of the Alabama Power Co., the Georgia Railway and Power Co., and the Tennessee Power Co.

In 1913 Birmingham began to receive power developed by the Alabama Power Co. at Lock Twelve, on the Coosa River.

From these centers transmission lines began to radiate; and extensions, ramifications, and interconnections have finally knit the Southern Appalachian region into the most extensive 110-kilovolt superpower system existing in the world today—a system with an aggregate mileage exceeding 5000 which is still growing vigorously, and no doubt will continue to grow for some years to come.

It may be of interest to review somewhat in detail the growth of this hydroelectric industry; and here are given some pertinent facts and figures.

The growth of the business of the Alabama Power Co. is shown in Table 1. This table shows that in the year 1920, 8.36 times as much power was generated as in 1914, and during 1922, 10.4 times as much—a growth of 1000 per cent in eight years.

The Georgia Railway & Power Co. began selling steam-generated power in 1903, and by the year 1914 had largely matured their market for power. Nevertheless, the total power either generated in their own plants or purchased by them from the Alabama Power Co. and the Tennessee Power Co. amounted in 1920 to 393,000,000 hp-hr., against 196,000,000 in 1914.

Table 1 Connected Load and Power Output of the Alabama Power Company

Year	Connected Load, hp.	Total Power Generated, hp-hr.
1913	16,500	26,000,000
1914	47,000	78,000,000
1915	62,000	171,200,000
1916	116,000	252,000,000
1917	184,000	394,000,000
1918	265,000	537,000,000
1919	287,000	476,000,000
1920	336,000	654,000,000
1921	362,000	584,000,000
1922	403,936	814,000,000

The Tennessee Power Co. began selling power in 1912. Their power output in 1914 was 304,200,000 hp-hr. In March, 1914, they began supplying power to the Aluminum Company of America, for the Maryville reduction plant; and during 1914 this company took 134,000,000 hp-hr., or about 44 per cent of the entire power output. In 1916 the Tennessee Power Co. generated 636,500,000 hp-hr., and the Aluminum Co. absorbed 64.6 per cent of the power sold. In 1917 the power generated was 735,000,000 hp-hr., and the Aluminum Co. used 62.45 per cent of the power sold. The Aluminum Co.'s peak load reached 54,000 hp. in that year; but later the load fell off, and in 1920 but 23 per cent of the power output went to the Aluminum Co., and in 1921, less than 8 per cent. On June 1, 1921, the Aluminum Co. ceased to be a customer, having completed its own power plant at Cheoah, on the Little Tennessee River. Yet so rapidly have the general requirements for power in the territory served by the Tennessee Power Co. increased, that the present generating capacity of 168,000 hp. is inadequate to meet the demand. The company is now building two additional steam plants, each of 27,000 hp. capacity, one at Nashville and one at the hydro plant at Hales Bar. The hydro plant at Great Falls is also being enlarged by the addition of a second 12,000-hp. hydraulic turbine.

All over the territory considered in this paper like conditions are seen. Construction of new power plants can scarcely keep pace with the growing demand for more power; and one authority recently remarked that the southern power companies are today 25 per cent behind the power market requirements. Everywhere intense construction activity is in evidence.

The Kentucky Utilities Co. is just completing a steam plant at Pineville having a present generating capacity of 40,000 hp. and a future capacity of 60,000, and will shortly start work on a hydro plant on the Dix River.

The Tennessee Eastern Electric Co. is adding to their two units on the Nolichucky River two more, and they will shortly be at work increasing the height of their dam from 35 ft. to 70 ft., thus more than tripling their present hydro generating capacity. They are also building a steam plant of 13,000 hp.

Both the Tennessee Electric Power Co. and the Knoxville Power & Light Co. have filed with the Federal Power Commission applications for permits to make very large developments on the Tennessee River, the Clinch River, and the Powell.

With a present generating capacity of 105,600 hp. of hydro and 30,800 of steam power, the Georgia Railway & Power Co. is just finishing construction of an 84,000-hp. plant on the Tugaloo River. In addition to this total generating capacity of 265,400 hp., this company owns 303,000 hp. of undeveloped or partially developed water power.

The Alabama Power Co. is just adding to its present generating capacity of 200,900 hp., 72,000 hp. more at the Mitchell dam on the Coosa River. Permits have been secured from the Federal Power Commission for four dams to be built on the Tallapoosa River; but before building these the company will first build plants to be called Upper Tallassee, Cherokee Bluffs, and Lower Tallassee, and will follow these by a plant at Lock 18, below the Mitchell dam on the Coosa. Designs for the first three of these are now being worked out.

So heavy has been the demand for power in these several states that for the last two years the Alabama Power Co. has leased the 80,000-hp. steam plant built by the Government during the war at

the nitrate plant at Sheffield, and this plant has served as an auxiliary to the constituent companies in the superpower system.

The Southern Power Company, with a present generating capacity of approximately 300,000 hp., will this year complete two new hydro plants, one at Mt. Holly, N. C., and one at Great Falls, S. C., which will add another 140,000 hp.

In addition to this, construction of two more steam plants with a combined capacity of 60,000 hp. will bring the total generating capacity of the Southern Power Co. to about 500,000 hp.

The growth of the power business in this region is further graphically shown by the diagram, Fig. 2.

The Changing Aspects of the Power Industry

What estimate, we should like to ask, would be made of the sanity of any engineer who might propose to pump water from a river flowing through Alabama into the Gulf of Mexico through a pipe line terminating in a reservoir located on another river, flowing eastwardly through North Carolina, into the Atlantic Ocean, 650 miles away? And merely for the sake of there using the water for developing power! Absurd as this proposal may seem, this very thing has virtually been done—though the pipe was solid, and made of copper. On a certain day not long since, copious rains occurred on the head waters of the Coosa River. The small reservoir of the Alabama Power Co. at Lock Twelve on the Coosa River was full, and so could not conserve this flood flow. The flow could be utilized, if at all, only as it came down the river; and passing over the dam, its energy would be forever gone. But away off to the east, on the eastern slope of the Piedmont Plateau, the reservoir of the Carolina Power & Light Co., on the Pee Dee River, had been drawn down, and an insufficient stream flow meant a shutting down, or at least curtailing of output, of the many cotton mills in and around Raleigh dependent on this water power. And so for a time the turbine gates at the Blewett Falls plant of the Carolina Power & Light Co. on the Pee Dee River were closed; and while the reservoir was thus allowed to be replenished by the flow entering it, the load of the company was carried by power relayed to it by the Southern Power Co., which in turn received it from the Georgia Railway & Power Co., to whom it was delivered by the Alabama Power Co.—power generated by the flood flow of the Coosa River! Here indeed was conservation doing real work!

This incident symbolizes the immense good which can and does come of the interconnection of large transmission systems. Among water-power engineers it has become a trite saying that interconnection converts secondary power into primary power. Recently, the manager of a large power company said: "Our company had completed the plans for a million-dollar auxiliary steam plant. But our experience since we became interconnected with our power neighbors has retired the plans to a filing cabinet. We believe now we shall not need the steam plant, or at least not in the immediate future."

In the Southern Appalachian region the fact that prolonged summer drought is the exception and not the rule, and the further fact that summer rains while frequently copious are also often closely localized, intensifies the obvious advantages of interconnection. Beyond this, the fact that a part of the region operates on eastern time and a part on central time introduces a diversity factor of no little value as contributing to the conservation of the water-power resources of the region. The process of interconnection has by no means more than begun, and one must indeed be a prophet who shall say where it will end.

The aspects of the power industry are changing so rapidly that we can see but a little way ahead. It is usually assumed that in the unfolding of the development of our water-power resources those power sites which can be the most cheaply utilized are those first developed; and that as the successive developments come in, the most expensive will come last. This, however, is not the case. Such would be the logical sequence if, at the outset, all our water-power resources had been fully studied, and all the complex factors entering the problem of each power development had been envisaged. The very fact that this logical order has not been even approximated gives a zest to the water-power game, as every hydroelectric engineer knows. In the Southern Appalachian region there are among the undeveloped water powers a number as large and certainly as attractive as any yet broken to harness.

Although according to the various reliable estimates of our total water-power resources we have as yet developed only a small fraction, the wonder is that we have made even this much progress. None but those in the business of water-power development realize the cost of making adequate preliminary investigations. Legislators and statesmen in particular have been slow to grasp the implication of this fact. It is for this reason that even today our knowledge of just what are our undeveloped power resources is not complete. There are, however, hopeful signs of a glad awakening; and perhaps the most significant of these is the Congressional approval of the recommendation by the chief of engineers for a real survey of the power and navigation potentialities of the Tennessee River basin. Think of what it means to national progress when the Chief of Engineers, and the Secretary of War can ask Congress to appropriate the sum of $515,800 for the survey of a single (if important) river system, and Congress can appropriate $200,000 for a beginning of this survey! The survey is now in progress, under the direction of Maj. Harold C. Fiske, Corps of Engineers; and two years will be required for its completion. In the meantime many surveys of single projects or of related projects are being rapidly carried forward by private interests.

The state of North Carolina, through the Geological and Economic Survey, by coöperation of certain counties in that state, is also carrying forward investigations within these counties. The State Geological Survey of Tennessee has now in press a Bulletin by J. A. Switzer describing a number of undeveloped water powers in Tennessee. In Alabama the legislature has just appointed a commission to study and report on the undeveloped water powers of that state.

A Study of Base-Load Steam Plants

The title of this paper, in referring to the coal power resources of the region under discussion, did not contemplate any detailed enumeration of the coal resources, but rather a discussion only of the problems connected with the development of large steam plants essential to the superpower system.

The installation of base-load steam plants at the coal-mine mouth has constituted an interesting and popular topic of discussion in all coal sections. To the layman it appears that the logical solution for the distribution of all coal-generated power is over the wires.

There are several advantages in such a system. It relieves the management of the generating station of the menace of a car shortage. It permits the use of certain low-grade fuels that it otherwise would not pay to use. It saves the freight charge on the coal that is used.

Other factors enter, however, that are of greater importance than those just mentioned. The most important one is the availability of adequate condensing water. Second only to this must be security of the coal supply—some form of anti-coal-strike insurance.

These two factors are of such predominating importance that to meet the requirements of a successful base-load station at the coal-mine mouth, it must be definitely provided that such a power plant must be located on a river which will give sufficient minimum flow to meet all condensing requirements, and that it must be sufficiently near a transportation system to put it in immediate haulage connection with several coal mines and, if possible, other coal fields.

Briefly, then, the requirements are a coal mine, a river, and more coal mines.

Of vital importance also is the matter of market for the power. Within the area covered in this discussion, the market is assured. The natural resources of the district are of such magnitude and diversity that the demand for power has grown in a much greater ratio than the power developments.

To emphasize the great influence which condensing-water supply must necessarily exert in selecting the location of the steam station, a typical water-demand curve is presented in Fig. 3.

Fig. 4 shows the river flow in cubic feet per second required to furnish condensing water for plants of various sizes when operating at $28^1/_2$ in. of vacuum, referred to sea level, and with cooling water at 60, 70, and 80 deg. fahr., respectively.

A study of Fig. 3 shows that for a vacuum of $28^1/_2$ in. referred to

sea level, with water at 70 deg. fahr., there is required a minimum of practically 385 tons of cooling water per ton of coal burned, on the basis of 9 lb. of evaporation. Most evidently the cost of securing condensing water is a very vital factor.

Not only is the quantity of water available important but its temperature also. Fortunately for the entire Southwestern Appalachian section, the water of the several streams is remarkably cool, usually being below 70 deg. fahr. even during the hottest weather. This is due to the source of the supply, practically all streams being fed by cold mountain springs. As we go out into the plains,

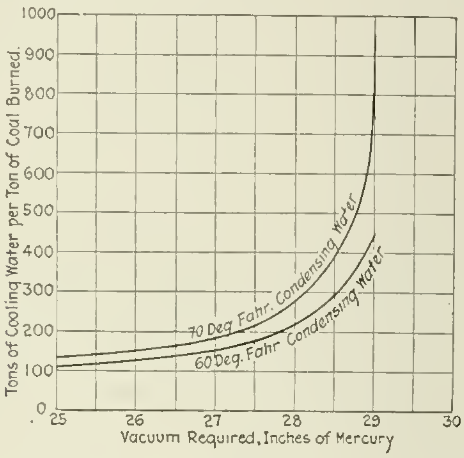


Fig. 3 Condensing-Water Requirements of Steam Power Stations
(Based on the evaporation of 9 lb. of water per pound of coal burned.)

however, river temperatures will average from ten to fifteen degrees higher than those of the mountain sections.

Where an insufficient volume of naturally cool water is available, the alternative of artificial cooling of a limited supply is some times to be considered. In this section spray cooling at midday during the height of summer cannot bring temperatures below 80 deg. fahr., and this temperature of condensing water precludes high-vacuum operation, since the boiling point of water at a vacuum of $28^1/_2$ in. is only approximately 90 deg. For the operation of very large steam plants, spray cooling is therefore of doubtful expediency.

For small plants, however, spray cooling is sometimes desirable; and when this is the case the mountain section again has an advantage over the lowlands for the reason that here lower relative humidities prevail, and hence the cooling effect of spraying is greater. An engineer of the authors' acquaintance was recently called in by a coal operator to install a 300-kw. non-condensing turbine. The water supply available was limited, and both the purchaser and the representative of the turbine manufacturer with whom the order had been placed felt certain that a condensing unit could not be considered. Both were amazed at the logic of the engineer, who finally convinced them that the scarcity of water actually made the condensing outfit the more desirable. When he proved to them that the loss of water by evaporation and by drift from a spray pond would be much less than the difference between the steam consumption of the condensing and the non-condensing turbine, the order was changed and the condensing turbine installed. Less actual water was required to operate the condensing unit!

Coming now to a consideration of possible sites for large steam plants, reference is made to Fig. 5. This map shows the location of operating coal mines, each dot representing a mine. The coal district reaches from the Harlan field in Kentucky to the Cahaba and Warrior fields in Alabama, with coal deposits well distributed in between. The Harlan district and the Middlesboro district of Kentucky hold some of the greatest coal operations of the entire Southern Appalachian region—many of these belonging to the great steel corporations. The section is well served by railroads.

The numerals on the map—seven in number—indicate what to the authors seem attractive locations for base-load plants. A thorough survey of the field would doubtless reveal others.

These locations may be briefly discussed as follows:

The Pineville, Ky., site (No. 1) is strategically located at the junction of two branches of the Louisville & Nashville Ry., leading to the Harlan and to the Middlesboro fields. This connection makes Pineville a center of coal transportation. The Cumberland River passes through the heart of the city and parallels the railroad for some miles. Several large coal mines are located close to the river at the outskirts of Pineville. Thus, the location has the requisite advantages for the location of a large coal-mine-mouth superpower station. The condensing water available is sufficient to provide during the very warmest and driest seasons for a generating capacity of from 75,000 to 100,000 kw. The Kentucky Utilities Co. now have under construction near Pineville a 45,000-kw. steam power plant to serve their system for this area.

The industrial demand of this section is such that the entire condensing capacity of the Cumberland River might well be utilized in the near future.

Passing southward, the second base-load steam plant indicated is located between Coal Creek, and Clinton, Tenn., on the Clinch River. This location is a few miles from any one coal mine, but sufficiently near to a group of good producing mines in the Coal Creek district to furnish coal by railroad for only a switching charge.

The condensing capacity of this river is sufficient to take care of a turbine capacity of from 400,000 to 450,000 kw. A large hydroelectric plant is being considered near this location at the present time, and the base-load site suggested is in very close proximity to a high-tension line now being built.

Plant No. 3 has been indicated on the map at Harriman, Tenn., on the Emery River. Like the Coal Creek site this location is not at any coal mine, but is suggested on account of Harriman's excellent railroad connections through four different carriers to four different fields. Several producing mines are only a few miles from the location. The minimum flow of the Emery River here

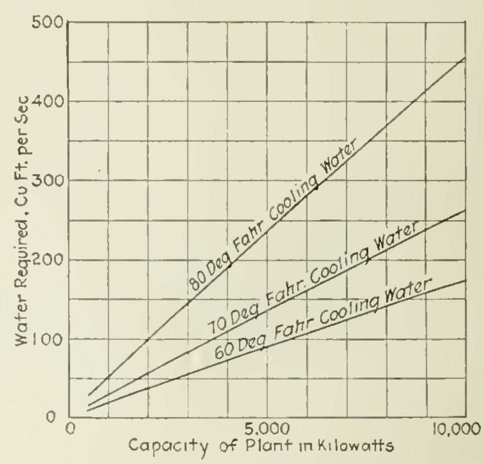


Fig. 4 Condensing-Water Requirements of Plants of Various Sizes When Operating at $28^1/_2$ In. of Vacuum Referred to Sea Level and with Cooling Water of Different Temperatures

will limit an installation to 75,000 to 100,000 kw. The water of this river is remarkably soft.

The fourth base-load plant indicated is on the Tennessee River, some miles above Chattanooga. This location would require the construction of a railroad approximately four miles long, extending from the base of the Soddy coal field. This would give the plant excellent railroad connection with both the Alabama and the contiguous Tennessee coal fields. It is interesting to note that one of the mines of the Soddy coal field, in the early period of its development, retained the transportation rights to the Tennessee River, with the intention of sometime using that stream as a transportation outlet. The size of this plant, as determined by the minimum cooling-water capacity of the Tennessee River, could of course mount into the millions of horsepower.

The fifth base-load plant site is at Hales Bar on the Tennessee River. Here a 20,000-kw. plant is already under construction near the Hales Bar dam. This site differs somewhat from those that have been suggested in that it will receive its coal supply by barge from several coal mines located on the Tennessee River near the Hales Bar location.

Quite probably the future power demand of Chattanooga will absorb a large portion of the power that might be produced in these nearby base-load plants—that is, if Chattanooga outdistances Pittsburgh as an industrial center!

The sixth steam plant indicated is the Gorgas plant already operating on the Warrior River. This 80,000-kw. plant is in the heart of the Warrior coal field. With the stream flow of the Warrior River available for condensing, this plant could be increased to much greater capacity.

On the opposite edge of the Birmingham district another base-load plant, indicated as No. 7, might well be placed near Helena, on the Cahaba River. Transportation lines come from both the north and the south through the Cahaba coal fields near this location. The minimum flow of the Cahaba River will probably limit the capacity of this plant to 20,000 kw.

The question is often asked why it is necessary to install such large central stations when a distribution of coal and of condensing water is more favorable to small plants. Aside from the much greater overhead cost of operating many small plants, we must consider the expense of connecting these small plants into a high-tension transmission system. The installation costs of the equipment for connecting in these stations (transformers, switches and lightning arresters) is so great per kilowatt of installed capacity as to be prohibitive. Fig. 6 shows the cost per kilovolt-ampere of transformers, switches, and arresters required to connect into a 110,000-volt transmission system. For capacities below 15,000 kw. these costs are very high.

By comparison of the curves of Figs. 6 and 7, the latter showing the costs of small turbo-generator stations, in this district it is seen that the unit costs of the small-plant switching and transforming equipment reach prohibitive figures.

The large base-load plant, stragetically located with respect to fuel, water, and transmission systems, will be a vital factor in the superpower system of the future.

The Labor of the Region

We turn now to the third division of our subject—man power. As pointed out in the able lectures on Southern History by Dr. S. C. Mitchell, professor of history in the University of Richmond, the greatest economic result of the Civil War was not the setting free of the negro, but the recognition and freedom offered the white people of the mountain sections. The Southern Appalachian

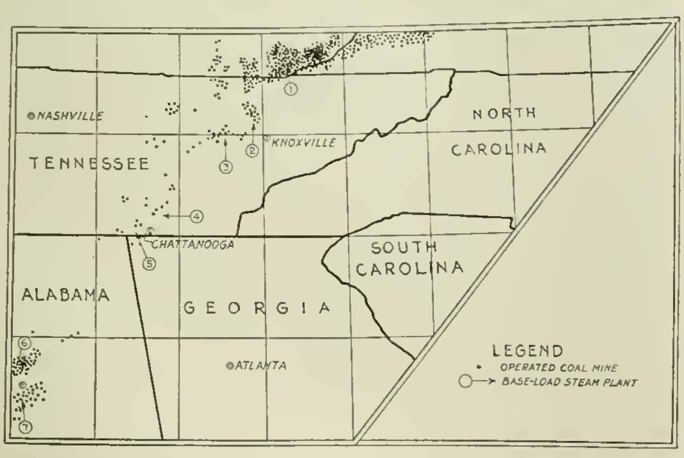


Fig. 5 Map Showing Distribution of Operative Coal Mines in the Southern Appalachian Region, and Desirable Locations for Base-Load Steam Plants

(Sites: 1, Pineville; 2, Clinton-Coal Creek; 3, Harriman; 4, Chattanooga; 5, Hales Bar; 6, Gorgas; 7, Helena.)

Mountains were peopled by an English, Scotch, and Irish stock that had taken to the mountains and hills, in refuge, apart from the cotton plantations. These people could not economically compete with the slave labor of the southern planters, of the plains. Rather than degrade themselves to practically peon existence in such competition, they moved to the mountain sections to earn a meager living on small tracts of tillable land.

In general characteristics these people differ widely from those of the plains. The very nature of the slave system made manual labor for the white people of the plains disgraceful according to their social thinking. On the other hand, for the mountain people manual labor was essential to existence. It was necessary for every one to work, and work was recognized as an integral part of their social community life.

In physical characteristics the mountain people differ from the lowlanders in that the higher altitude and lower average temperatures have permitted them to move faster. This together with the greater physical ruggedness necessary to cultivate and travel the mountain slopes has given them a great advantage over their

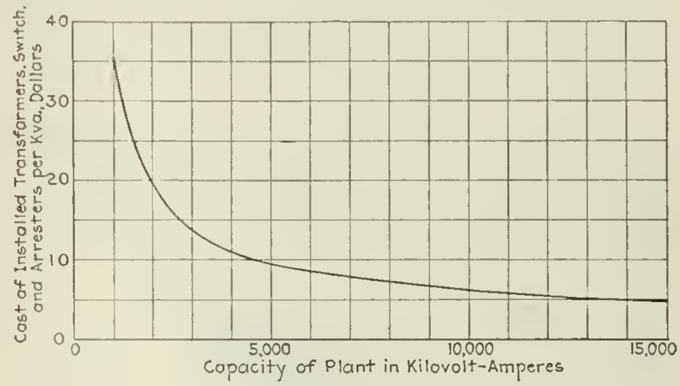


Fig. 6 Cost of Connecting Small Generating Stations into a 110,000-Volt Transmission System

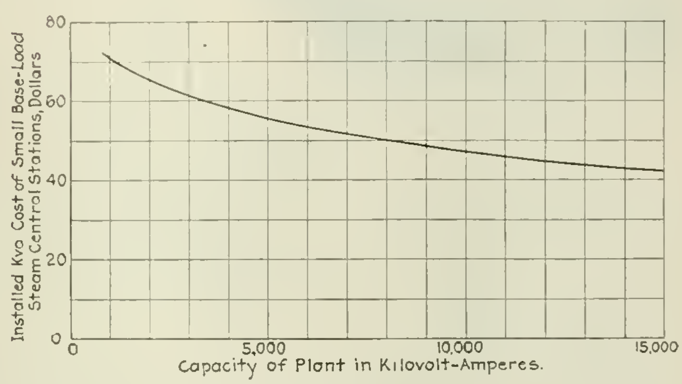


Fig. 7 Cost of Installing Small Base-Load Turbo-Generator Stations

brothers of the plains. The greatest handicap that the mountain folk have experienced in their physical development has been the vicious attack of the hookworm. While in many sections today this is entirely under control, yet the inroads made will be in evidence at least for another generation.

To this mountain stock that was so carefully preserved through the slave period, the South owes much of its present industrial development. The freeing of the slaves produced on the plains, a chaotic condition. The colored man was enjoying a new freedom which he did not know how to use. The plantation owners were helpless in that their fortunes were depleted and they had been trained to look upon labor as degrading. Thus, the men to save the situation were these sturdy mountaineers. They knew the South, they knew how to work, and they knew how to exist on a very meager food supply. In many of their homes the staple food for years had been the "three m's"—meat, meal, and molasses; thus they were inured to hardship.

It is this same stock today that is the potent factor in the industrial development of the South. It is the source of supply of some of the best labor and brains in America. While a textile mill in the very midst of the cotton-plantation areas is frequently in distress, in the mountain towns and those cities drawing their labor supply from the mountain areas the looms have been spinning prosperously for the past decade, with every evidence that within the next few years the textile-mill Mecca of America will be the Southern Appalachian slopes.

A study of Fig. 8 will reveal graphically the race composition of these mountain slopes. The basic data for this map were taken from the 1920 United States Census. Several counties within the

area covered by this study have less than one colored person per thousand inhabitants. Within these counties the face of a colored man is less commonly seen than in most of the industrial centers of the North.

The relatively small colored population of these mountain counties is not the only remarkable condition, for the percentage of foreign-born population is still lower. The foreign-born populations of North Carolina, South Carolina, Georgia, Alabama, and Tennessee are all less than one per cent. This can be more fully appreciated by comparison with Pennsylvania with its 15.9 per cent, New York with its 26.8 per cent and Wisconsin with its 17½ per cent foreign-born population.

In the seven states included as a whole or in part in this study, viz., Alabama, Georgia, North Carolina, South Carolina, Kentucky, Virginia, and Tennessee, an area whose total population is over fifteen million people, there are only 124,391 foreign-born inhabitants. When we compare this with the smallest state of the Union, Rhode Island, having a total population of only 604,397 according to the 1920 census, of which 173,499 were foreign born, the contrast is striking.

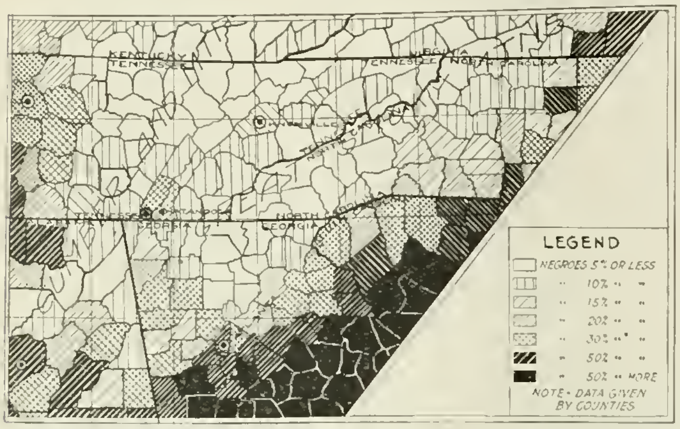


Fig. 8 Relative Densities of White and Black Population in the Southern Appalachian Region

With the enforced restriction on labor immigration to American shores, the home supply of workers and of employment is being more closely surveyed. The assembling in large industrial cities of large aggregations of workingmen living under unhomelike surroundings has never solved any of our labor troubles, but on the contrary has engendered a host of disturbances.

While in many industrial centers this condition has been growing worse and worse, a far different system has set itself up in the southern districts. Briefly, the mills are locating near the homes of the workers in the small towns and cities instead of in the large industrial centers. For decades men have located large manufacturing plants in large cities with a beckoning finger to the working man or the working woman to leave the home surroundings and come to them. The result has been overcrowded cities, with employees forced to adjust themselves to unhappy conditions of both living and working.

Today over the Southern Appalachian slopes we find hundreds of small manufacturing plants locating in the small cities. These mills are not seeking alone cheap power and cheap transportation. The greater consideration is a reliable and contented labor supply. These plants are being located where the adjustment of the home life is but a matter of turning one's footsteps in the direction of the new mill where the income in dollars and cents is higher than that to which one has been accustomed.

The new mill soon becomes a recognized home industry. With enlightened management, the life and interest of the worker are soon closely associated with that of the organization and he thinks of it as a part of his home—and of himself as constituting really a part of the organization.

A survey of these plants will show that labor disturbances are rare. There are sufficient duties in the long-established home, in the church, and in the town to occupy the free moments of the workers. The likelihood of assembling for other than very real grievances is remote. Occasionally some difficulty arises from the activities of over-zealous local politicians, but usually such activity soon loses its color and influence. The professional labor agitator has not become acclimated to this region.

On the eastern slopes of the Appalachians this movement of the mill to the labor has been the most marked. In some counties of the Carolinas the mill saturation point has about been reached. Like all similar movements, it is traveling from east to west. On the Southwestern Appalachian slopes the movement is still in its infancy. There still exists within the region outlined a great reservoir of American-born labor that for many industries will provide the solution of the labor problem for many years to come. And the value of this labor supply will become better appreciated as the regulations dealing with foreign immigration become more stringent.

The reaction of this industrial growth upon the social life of the worker himself is markedly beneficial. The elimination of the hook-worm disease, the introduction of better community sanitation, and the inevitable relegation of the senseless family feud to the scrapheap of ancient customs will all lift from the mountain folk a burden of hardship the depressing effect of which they themselves have not recognized. The responsiveness of these people to the higher social standards of the more enlightened environment into which they come when some of them move down into the larger cities of the region is an outstanding characteristic.

In the preparation of this paper its authors have intended to exercise due restraint. It has been their thought rather to suggest the industrial possibilities of the section than to paint them in glowing colors. If the paper shall contribute in a slight degree toward a broader knowledge of the Southern Appalachian mountain region, its purpose will be met.

Labor Versus Mechanical Power

According to figures recently issued by the United States Bureau of Immigration, less stringent immigration laws will not solve our labor problems. During the year ended June 30 last, immigrant aliens to the number of over 500,000 entered this country. Only about 80,000 of these were laborers as against over 100,000 skilled workmen and nearly 200,000 women and children without any occupation. This ratio is not unusually low, but about the average. As long as this condition exists, anything that may be done to remedy a shortage in common labor by releasing the restriction against aliens entering this country will aggravate the situation rather than help to solve the problem, on account of the large number of unsought-for persons entering at the same time.

A solution of the future labor problems is not to be found in more labor, but in less labor and a greater use of mechanical power. Great advancements have already been made in this direction, but a great deal more has to be done.

In this country higher wages are paid than in any other country of the world—in some cases two or three times those paid in foreign countries—yet American industry can compete in the markets of the world. This has resulted from the use of power, making it possible for one worker to produce with a machine what required several to do by hand. In 1869 an average of six-tenths horsepower was used in this country per wage earner; by 1919 this figure had increased to over three and one-quarter horsepower, which follows along a similar line as the average increase in wages during this period.

Although the use of more efficient methods in industry is primarily in the hands of the management, nevertheless labor has its responsibility. If labor is going to continue to demand a higher wage for its services, it must expect to coöperate to make its efforts more productive. Estimates show that there are over two hundred thousand more miners in the coal industry than required to produce the country's coal. This is with present methods; if modern methods were generally introduced in the coal-mining industry, this figure would be greatly increased. The coal industry is one of the worst offenders, but it is by no means the only one responsible for labor wastes in industry. Until such wastes are eliminated it will be difficult to see where more labor is required.—*Power*, vol. 58, no. 13, Sept. 25, 1923, p. 563.

The Chemical Warfare Service—Its Activities and Achievements

THE Chemical Warfare Service represents the most advanced application of science and engineering to military purposes. Its activities are those of scientific and technical warfare in its highest phase. Undoubtedly its already recognized effectiveness is due to the fact that it has applied processes and methods to military purposes which have already brought about revolutionary results in civil life in peace times.

Chemical warfare is a very recent development, its first effective employment having been on the memorable morning in April, 1915, when the Germans discharged a cloud of chlorine against the Canadians in the Ypres section. From that crude beginning in less than ten years a comprehensive and effective service has developed which now comprises among its functions not only the use of gases but also the provision of means for the detection of and protection against gases, the use of smoke screens, signaling means, and inflammable materials, and many auxiliary features.

The ancient discovery of the bow was the first rude application of engineering to warfare, requiring as it did a considerable amount of thought and knowledge in the selection of proper materials for the bow itself, the bow string, and the arrow. Thousands of years later chemistry revolutionized the methods of armed conflict by the invention of powder. From then on progress was rapid, resulting finally in the evolution of the present high-speed automatic rifle and rapid-fire gun on one hand, and the immense and complicated artillery guns on the other.

In one way, however, the rifle and gun were merely outgrowths of the bow. Just as the bow shot out an arrow which had to reach its human mark in order to be effective, so the rifle and gun threw a bullet or shell. The range and force of penetration were tremendously increased, but the mode of action remained essentially the same.

To some extent shrapnel and high-explosive shells departed from the old bow-and-arrow principle in that they made it possible to create a small "area of destruction." This area, however, remained extremely small and furthermore had only what might be called a momentary effectiveness, only those being endangered who happened to be within the area when the explosion took place.

The New Element in Warfare: The Gas Attack

Chemical methods of warfare in their use of gases [this term is used here merely because it has become familiar to the public; actually, however, the majority of gases used in warfare are not gases at all, but either liquids or solids which are atomized or scattered by the booster charge of the shell] have brought a new element into combat. In the first place, they have made it possible to attack extensive areas—whole square miles today, and possibly hundreds of square miles within the next few years. In the second place, the new method of warfare provides for attacks which are not merely momentary in their duration as are those by shrapnel or high-explosive shells, but which extend over considerable periods of time. Thus, a trench properly sprinkled with mustard gas would be dangerous to stay in even after several days. In the third place, a "timed" attack becomes possible, and in fact was used in at least one instance iu the last war. A section of a battlefield can be covered by shells timed to explode several hours after they fall on the ground. Such a region would become dangerous only after these shells had exploded and had discharged their lethal contents. This is somewhat like the timed-fuse mine of an earlier day but vastly easier to handle and more efficient.

The most significant thing about the Chemical Warfare Service is the spirit in which the work is carried on. For example, at Edgewood Arsenal, which is its research and manufacturing headquarters, practically the entire research personnel are civilians, though the executive staff consists of commissioned officers. The men who are developing the gas and gas protection, smoke screens, etc., know nothing of Clausewitz and Vauban and are even ignorant of the most elementary principles of drill, but they understand everything about chemical valences and modern factory production methods. They are not soldiers at all but merely engineers, scientists, and chemists engaged in developing the best methods of efficiently killing one set of human beings and protecting another set from being killed, and are applying to their work the same methods, practices, and devices that have proved their efficiency in the manufacture of shoes, rails, and typewriters. Those who still talk about the romance of war would have a rude awakening were they to go through the laboratories of Edgewood Arsenal and see how this romance of warfare is being prepared in the test tubes of organic chemistry.

Early Work of the Chemical Warfare Service

When the Chemical Warfare Service first set about its work, in the summer of 1917, our knowledge of gases used in warfare was very limited and it was thought that complex mixtures consisting of three, four, or perhaps five materials might have to be used as fillers for shells. Because of this an elaborate mixing apparatus was installed consisting of a system of piping leading from various supply tanks of materials. These pipes led to five-way valves, Fig. 1, which could be operated from the outside of the mixing building, so that the leakage of the poison material would not affect the operator. The latter likewise from the outside of the building could see the temperature of each of the materials and the amount of material which filled the mixing tank.

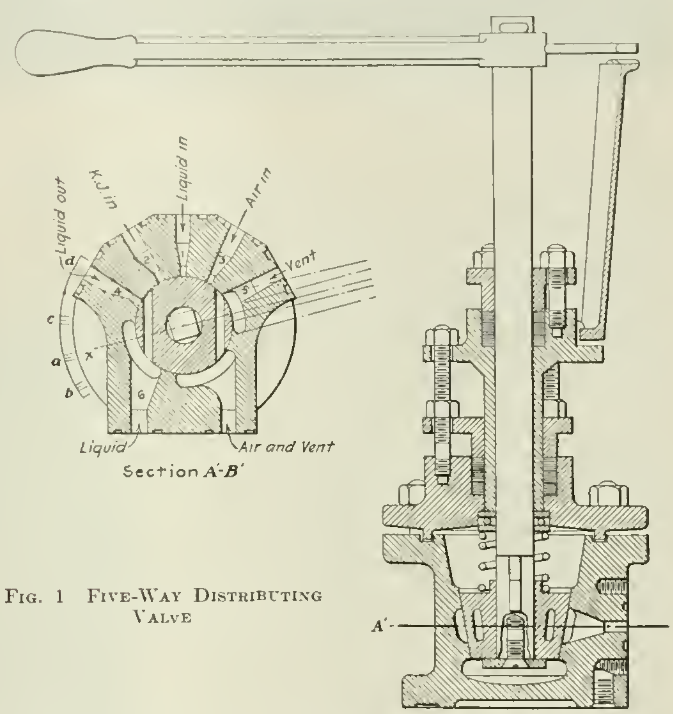


Fig. 1 Five-Way Distributing Valve

These mixing outfits are remarkable for the ingenuity of their design and the success with which the difficult and dangerous problem has been solved with comparatively simple means. It was found later, however, that all this work had been entirely unnecessary, as in actual practice materials such as phosgene and mustard gas proved to be far superior not only from the point of view of manufacture of shells but also because of their casualty-producing effect as compared with that of the originally projected complex mixtures.

Edgewood Arsenal as it stands today still embodies the basic idea with which it was developed, namely, that of attaining a maximum production within the shortest period of time, so as to relieve the hard-pressed armies of England, France, and Belgium on the western front in 1918. Much makeshift machinery still remains. The engineers of the arsenal realize that better machinery could have been designed and undoubtedly know how to do it,

Fig. 2 Plant at Edgewood Arsenal for Filling Shells with Phosgene

but in those days it was not the most efficient but the easiest available machinery that had to be selected. Nevertheless it does the work, and that is the most important thing.

Shell-Filling Machinery at Edgewood Arsenal

From this point of view the shell-filling machinery is of great interest. There are two types of it installed—one of the constant-level type used for filling shells with phosgene, and the other of constant-volume type for filling shells with lachrymators.

In the phosgene-shell filling plant the first problem is to chill the phosgene to the point where it will not evaporate. This is necessary in order to permit the workmen to handle the machinery without gas masks, thus increasing the efficiency of work many times and also providing for greater safety of the men. The phosgene containers from the generating plant are made to pass through a long room kept at a low temperature by means of ammonia coils. From these the phosgene is discharged into tanks having six spring-controlled outlets (Fig. 2). The level of the liquids in the tanks is maintained constant by means of flood-control valves. Six shells at a time are brought by a chain traveler into proper position below the outlets referred to above. The operator then pulls a lever which lifts the shells and presses their necks against a spring-controlled collar. This opens a valve and permits the liquid to flow until it reaches the same level in the shell that it has in the tank, which is equivalent to the proper charge of phosgene for the given type of shell. After a little practice the operators know exactly how long to keep the shell against the collar in order to have it completely filled. From the filling station the shell travels to the next position where the booster is screwed into it, and then goes to the inspection department, after which it is ready to be shipped to the battle front.

The constant-level type of apparatus has the disadvantage that it has to employ several valves of comparatively small size. This disadvantage becomes serious when the filling liquid is of a highly corrosive nature, in which case the constant-volume type has to be used (Fig. 3). This kind of machinery is essentially somewhat similar to the gasoline pumps used for filling automobiles. A given amount of liquid is discharged into a container just sufficient to fill one shell. When the container is full, the shell is pressed against an outlet with a spring-controlled valve and the liquid is transferred to the shell. Those who enter the constant-volume shell-filling plant have a good illustration of the truth of General Sherman's famous saying as applied to modern warfare. While no shell filling has been done in the plant for over two years, the walls are nevertheless so permeated with the vapors of the lachrymators that escaped into the atmosphere when work was being carried on, that it is impossible to remain inside for more than a couple of minutes without having the eyes smart and water.

Because of this condition and also of the impossibility of preventing some escape of the shell-filling material into the atmosphere, great care has been paid to the ventilation of the buildings containing the shell-filling plants. The phosgene-shell-filling plant is equipped with a powerful double ventilation system, in addition to which as a reminder of the character of the work being done there, a row of masks are hanging on the walls within easy reach of the men.

Other Work Carried on at Edgewood Arsenal

At Edgewood Arsenal it is no unusual thing to encounter familiar equipment used for novel purposes. Thus, there is a battery of gas producers. These are used for making carbon monoxide, which, in its turn, is further converted into phosgene. The gas producers are supplied with a mixture of carbon dioxide and oxygen and are said to operate under these conditions with perfect reliability and great efficiency. Because of the character of its work, which of necessity must be highly confidential in many of its phases, and also because of its location in practically open country, the Edgewood Arsenal has to rely largely on its own resources. It is magnificently equipped to do so, having a power plant of its own, a large refrigerating plant, splendid chemical and physical laboratories, and in addition an extensive and well-equipped machine shop.

In connection with the latter, there are one or two features which deserve special mention. It is no unusual thing for some of the men to have to work nights or Sundays in order to complete a piece of machinery needed for some research work or a rush repair job. In order to secure greater convenience in this kind of work when but one or two men have to remain in the shop alone, an emergency bay has been arranged in which the most important machine tools are grouped together in such a manner that one man can take care of two or three simultaneously. The same rather unusual care and thoughtfulness is evidenced in other directions. A small but significant indication of it is shown in the handling of reamers. What every one should realize but many do not is that the reamer is really a delicate tool and should be handled with about the same care as a razor. It is the rough handling of reamers that dulls them much more than the actual cutting. At the Edgewood Arsenal every reamer when it is returned to the tool room is inserted in a thick paper tube which protects it from scratching against the case and from the action of the atmosphere. It is claimed that reamers last twice as long with this arrangement as they would without it.

An Outdoor Anemometer

The true character of the Edgewood Arsenal work and what it stands for does not become apparent until one reaches the departments of physics and chemistry. As an illustration of what is being done there, Dr. T. B. Hine's department of field work may be mentioned. The great importance of smoke screens in warfare is now unquestioned, but the persistence and spread of smoke screens depend on the character of the atmosphere into which they are projected. It becomes important to the modern soldier to know the state of the atmosphere. The old bowman also had to know it, but as the precision of his knowledge could not be very exact, he accomplished his purpose by wetting the finger and sticking it up in the air. The modern scientist-warrior, of which Doctor Hine may be taken as a representative type, is not satisfied with such crude means. He wants to have not only an exact knowledge but a true record of the state of the air with all its eddies, turbulence, and shifts of direction of the wind. To do this an outdoor anemometer has been developed using the same principle as that proposed by Professor King of Canada, namely, the variation in temperature of a hot wire exposed to the air. The apparatus has not yet reached its final stage of perfection, however, and while it does give the

desired information, it is somewhat clumsy to handle in open country. A type is being developed which promises to satisfy the conditions of portability as well as that of precision.

A New Gas-Sampling and Analytical Method in Use at Edgewood Arsenal[1]

A new method of sampling and determining very small quantities of foreign gases in air has been developed and is in use at Edgewood Arsenal for field experimentation. This method has proved so useful in this work that it may be of value in the control of certain industrial waste gases or studies of atmospheric pollution by industrial plants. The method consists of two essential parts: (1) A portable machine for drawing and measuring large samples of air; (2) A special charcoal cartridge to absorb the foreign gas from the air sample and a laboratory analytical method of determining the quantity of foreign gas absorbed in the charcoal. The analytical method consists of combustion of the charcoal, absorption of part of the gases of combustion in a suitable solution, and determination of the quantity of a certain element characteristic of the foreign gas, using ordinary analytical methods. In the field work at Edgwood Arsenal many of the gases to be determined contain chlorine, hence this element is the one determined in the gases from the combustion of the charcoal. The method can obviously only be applied in case the foreign gas to be determined in air contains some element other than hydrogen, oxygen, nitrogen, and carbon, but this still leaves a large field of possible application including such substances especially as the sulphur dioxide or sulphuric acid fumes from smelters and many chemical industrial waste gases.

If we wish to determine very small quantities of foreign gases in the atmosphere it is necessary to take quite large samples, and it is desirable to be able to adjust the size of sample somewhat to the concentration of the foreign gas. The use of evacuated flasks or

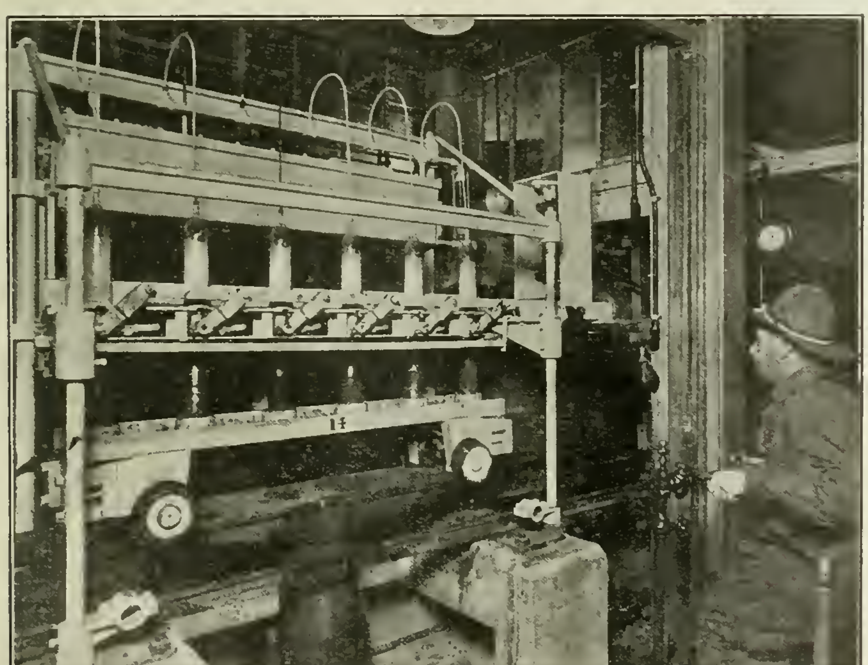


Fig. 3 Filling Mustard-Gas Shells

water aspirating bottles which are often used for gas sampling become very clumsy if not impossible when large samples and portability are desired. The apparatus for drawing a number of large samples as used in the field experimentation at Edgewood Arsenal is shown in Fig. 4.

When the sampling machine is in action an air pump driven by an electric motor draws six samples of air simultaneously through six calibrated flow meters at the rate of 20 liters per minute. The charcoal absorption cartridges or other absorption apparatus which may be in use are at the end of long rubber tubes which allow the samples to be drawn from any desired points within a reasonable radius of the sampling machine. The rate of flow of the gas is adjusted to allow for the different resistances of the individual absorption cartridges by means of the needle valves on the front of the machine. A further adjustment, which, however, is not always necessary, is provided in the shape of an opening from the

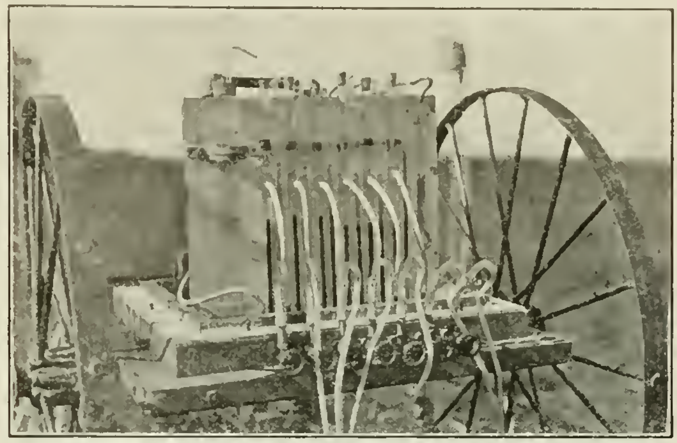


Fig. 4 Apparatus for Rapid Air Analysis

(The air under examination is passed through tubes containing activated charcoal which absorbs certain impurities.)

suction side of the flow meters to the atmosphere which is controlled either by a needle valve or by bubbling the air through a constant head of water. The water bubbling flask is disconnected in Fig. 4.

Since the flow meters are calibrated at one definite pressure and are run at various pressures due to the varying resistance of the absorption cartridges and connecting tubing, it is necessary to measure the pressure on the suction side of the flow meters while the sample is being taken in order that the true volume of the sample at atmospheric pressure may be calculated. This pressure is measured by a mercury manometer. It should perhaps be mentioned that the 1-hp. motor employed is much larger than required to drive the pump and was only used since this was the smallest 220-volt d.c. type available in sufficient numbers at the arsenal when these machines were built. The power to drive the motors on a number of these machines is supplied by a portable generator driven by a gasoline motor.

A number of liquid absorbents in different forms of apparatus were tried before the charcoal cartridge was developed, but none of these were completely successful in removing minute traces of chemically rather inactive gases from air. Ordinary activated charcoal such as is used in gas masks was found to remove the gases from the air, but all attempts to determine the amount of them in the charcoal were unsuccessful. Finally a special charcoal was made which was essentially free from chlorine and gave no ash when burned. With this charcoal entirely satisfactory results have been obtained when analyzing air containing chlorpicrin or mustard gas.

A satisfactory activated charcoal free from ash and chloride can doubtless be made in a number of ways, but the exact procedure found to give a satisfactory product is here given in detail:

> Mix thoroughly 485 g. of light cylinder oil with 120 g. of lampblack, both tested to assure freedom from chlorides, transfer the resultant paste to an iron retort provided with a vent, and heat the retort in four hours from room temperature to 800 deg. cent. Hold the temperature at this point for 20 hr. At the end of this time the retort is cooled and the charcoal is passed through a 10-mesh sieve and caught on a 16-mesh sieve. All material passing the 16-mesh sieve is rejected as fines. The remainder of the charcoal is now ready for activation.
>
> Since the finished charcoal must be as free from chlorine as possible, extreme care must be exercised to prevent contamination of the charcoal, both during and after activation. The activation is carried out in a $^3/_4$-in.

[1] This description of the method has been kindly contributed by Dr. T. B. Hine. The laboratory work on the method was mainly carried out by A. H. Huisken and A. M. Rowe, working under the direction of Dr. Hine.

silica tube heated in a vertical tube furnace. The bottom of the tube is loosely stoppered with asbestos fiber and the top is connected with a distilling flask in which steam is generated from distilled water. To activate the charcoal, fill the tube to the height which the furnace will heat and place it in the furnace, which has been previously heated to 875 deg. cent. Pass steam through the charcoal for 35 min. Water gas is formed at this temperature and the time should be measured from the first appearance of water gas. This may be detected by testing the exit gases for combustibility. After the steam treatment has continued for 35 min. disconnect the steam and heat the charcoal for 5 min. to remove residual moisture. Empty the contents of the tube into a Pyrex flask before it cools, stopper the flask tightly, and cool. This charcoal will be found suitable for use.

Charcoal prepared in this way contains about 0.001 per cent of chlorine as shown by the combustion of a series of 5-gram cartridges. This charcoal will absorb about 10 per cent of its own weight of chlorpicrin before letting any detectable amount through, and this is a hundred times the amount required in a sample for accurate analysis. The charcoal cartridge used in field work contained 5 grams of the special charcoal supported on a little

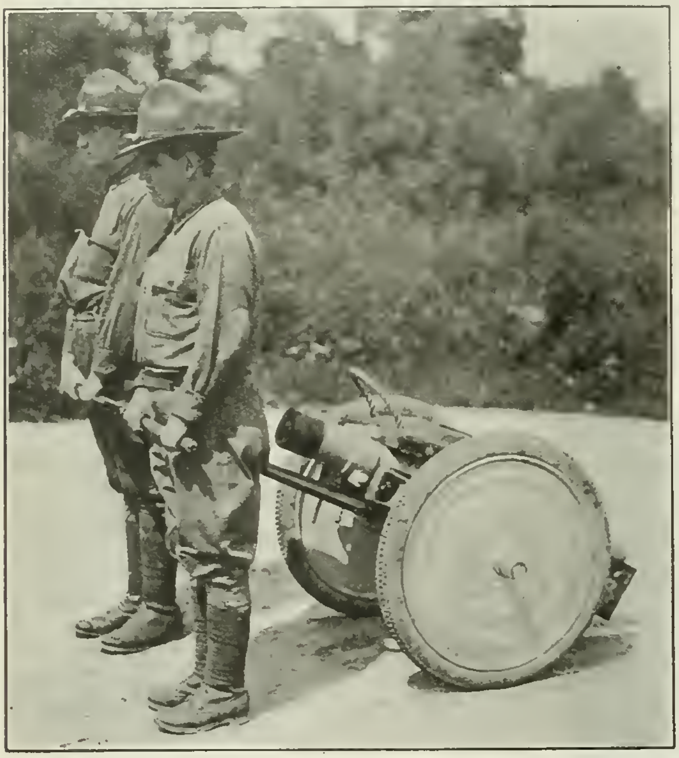


Fig. 5 One Type of Cart Developed for Transporting a Stokes Mortar

glass wool at the constricted base of a glass tube about 1 cm. in diameter.

The combustion of the charcoal is carried out in alundum boats in a silica tube using oxygen and an electric combustion furnace. A section of the silica tube in the furnace beyond the sample boats is filled with silica chips previously very carefully cleaned by boiling with hydrochloric acid and washing free from chlorides. These chips assure the complete breakdown of any organic compounds that might otherwise be distilled out of the tube without combustion. The gases of combustion are scrubbed in tall absorption towers filled with glass beads and, when chlorine and hydrochloric acid are to be caught, containing a solution of sodium sulphite and bicarbonate. The chlorine content of this scrubbing solution is determined either volumetrically or gravimetrically by well-known methods. Since the chemicals used in scrubbing and analysis are difficult to obtain wholly free from chlorides, a blank is first run and this chlorine content subtracted from the results of each analysis.

The percentage accuracy of the method depends upon the quantity of the foreign gas absorbed in the charcoal. If the quantity of absorbed gas is not much below the equivalent of 10 milligrams of chlorpicrin, it can be determined within about 1 per cent. In actual field work when large numbers of samples are taken and analyzed it is found that samples taken at the same place and time will not always check quite this closely. When drawing samples of about 100 liters it was found that duplicate samples when containing 10 milligrams or over checked within about 3 per cent, when containing 5 milligrams or over, within about 6 per cent, and when containing 1 milligram, within about 15 per cent. This may not at first sight appear to indicate much accuracy, but when we consider the minute concentrations in the air which we are determining, the accuracy appears remarkably high. A concentration of 10 milligrams of chlorpicrin in 100 liters means about 0.0015 per cent by volume or 15 parts per million, while the 1 milligram which can be determined within about 15 per cent represents in this case a concentration of only 0.00015 per cent by volume or 1.5 parts per million parts of air. This represents an accuracy of analysis which at least to our knowledge has never been attained before in the routine analysis of a large number of samples.

Solving the Problem of Spraying Liquids from Airplanes

One of the most recent developments promising important results from both a military and a civilian standpoint deals with airplane sprays. There have been many attempts to spray liquids from airplanes, none of them, however, being successful. It is obvious that if liquids could be sprayed in such a way as to reach the ground without excessive loss, important results could be achieved. Thus, for example, if in war time an area could be properly covered by a fine rain of mustard gas, it could be made uninhabitable for a considerable period of time. On the other hand, in peace time equally desirable results might be achieved by the application of calcium arsenate to a cotton field infected with the boll weevil. It appears that hitherto whenever this has been attempted the liquid would mysteriously disappear in the air without reaching the ground. Dr. Hine, however, has solved the problem.

From previous investigations, in particular those of Leonard, it would appear that a drop of liquid falling from a great height, such as from the clouds, at first accelerates in accordance with the general law of the earth's gravitational field. In doing so it encounters a resistance on the part of the air which increases in a certain ratio with the speed, and this resistance tends to retard the drop on one hand and decrease its size on the other. It would appear that for water a drop reaches a state of equilibrium at a diameter of 4 mm. (slightly under $^1/_6$ in.), which means that at this diameter the drop falls at a constant speed and retains its size and shape. This is one of the reasons why raindrops are so uniform in size and why extremely large drops come only from very low-lying storm clouds.

Were it possible for an airplane to remain stationary when liquid was being sprayed from it, the drops in falling would break up in exactly the same way as do raindrops, would reach a standard size of 4 mm. diameter for water and diameters for other liquids corresponding to their viscosity and specific gravity, and would ultimately reach the ground. As a matter of fact they do not, which is due to the fact that as the liquid is sprayed from an airplane it is picked up by the powerful air stream coming from the propeller and immediately broken into a mist which naturally has no means of reassociating into larger drops and hence does not fall on the ground as a spray.

What Dr. Hine did was to discharge the liquid under pressure from a hose located in such a manner and at such a distance from the main body of the airplane that the spray was initially delivered into a comparatively quiet stratum of air. As a result of his work, means have been found to deliver a spray not only without excessive loss but in such a manner as to cover definite areas of ground. Thus, at a recent demonstration at Edgewood Arsenal, the officers of the War and Navy Departments were sprayed from an airplane with perfumed water.

Development of a Portable Trench Mortar

One of the interesting things which "may be told now" deals with the development of a portable type of Stokes mortar. The original, mortar, an English invention, proved for all its simplicity one of the most useful tools of trench warfare. Essentially, the Stokes mortar is merely a tube closed at the bottom. A shell

(Continued on page 669)

Modern Subway Cars and Their Operation

As Exemplified on the City Owned Rapid-Transit Lines in New York

By SELBY HAAR,[1] NEW YORK, N. Y.

THE subject for consideration at this session is really the steel passenger car; on account of the breadth of the theme, however, the author will confine his remarks to steel cars in New York City, and particularly in the city-owned subways. The paper has purposely been made brief, to permit full discussion in order to record, before it is too late, the early history and the influences which molded the development of a piece of apparatus which all but monopolizes its field, and which now engages millions of dollars of invested capital, calls for the employment of tens of thousands of skilled workmen, and is turned out by the thousands every year—all of which has grown up in the twenty years since a sample car was built for the New York subway at the Altoona shops of the Pennsylvania Railroad Company. An invitation is extended at the outset for the contribution of all pertinent information on the subject, particularly reminiscences of the early days.

The successful operation of the New York Subway and all modern passenger subways was made possible by:

1 The electric system of power generation, transmission, distribution, and application to trains, particularly the multiple-unit system of motor control

2 The block-signal system of train control with high track capacity; and

3 Last but not least, the steel car.

There is room for argument that (1) may be divided into several items, but for the present paper such subdivision is unnecessary. The selection of these features was made with two points of view in mind, economics and safety.

Nowadays it may scarcely be believed that there was grave doubt among many unbiased students of the New York transportation problem 25 years ago that the subway would earn a profit, and hence the present generation are amazed to hear of the risks that the contractor took who signed the first Interborough subway construction and operating contract in 1900. Economic necessity dictated that the power system should be of high efficiency, that the length of trains should be capable of increase as much as was warranted, that the construction and maintenance costs of the cars should not be much, if any, greater than such costs for wooden cars, and that the signal system should permit the safe operation of trains at headways closer than had been before attempted. How successfully these requirements were met is a matter of common knowledge.

Time does not permit a discussion of the electric power system and the signal system from the safety standpoint, any more than to say that they have met all expectations fully. The author, however, must call attention to one important feature of the signal system, namely the automatic track trip, which is lowered when the block with which it is associated is free of trains, and is raised when the block is occupied. If a train passes over a raised track trip, an air valve on the truck and connected to the air-brake system is struck and opened, causing an emergency application of the brakes; thus a train already in a given block is protected from a rear-end collision. This feature is essential to permit the short headways that are scheduled.

The steel car was produced by Mr. George Gibbs, consulting engineer to the Interborough Rapid Transit Company, to eliminate fire hazard from subway operation, for which purpose it has been a success. The author is informed that at least one all-metal railway car was built many years ago, but subway limitations of size, weight, and manufacturing cost compelled the development of an entirely original design. Attempts had been made to produce car bodies that would not burn by building them of asbestos in molded and board forms, and also by searching for a method of fireproofing wood, but the steel car was recognized as the real answer to the problem. To assist in gaging the seriousness of the danger, consider the following facts: A fire in one train would threaten a large number of people, 1000 to 1200 in 1903, 1600 to 2000 at the present time. A fully loaded express train draws momentarily from the power system every time it starts from rest, that is, every few minutes, 4000 kw. (approximately 5300 hp.), which is nearly twice the (horsepower) capacity of the most powerful steam locomotive in this country. The power system which is adequate to meet such demand is of such enormous capacity that a dead short-circuit under a car might easily amount to 100,000 amperes, which at 600 volts would be 60,000 kw. A current of that magnitude would produce such intense heat in a fraction of a second as to consume utterly any wood near it, not to mention the explosive effect of the sudden heating of air and moisture in the confined space of a subway tunnel. It is to be noted that not only is the car body constructed of incombustible materials (with a few exceptions), but, furthermore, the steel is an electrical conductor which forms a part of the power circuit (grounded side), so that any failure of insulation which might cause a fire is converted promptly into a short-circuit, and the power supply disconnected directly. The lower the resistance of a short-circuit, the more quickly the safety devices act. Not only is the insulation of the electrical conductors composed as far as possible of incombustible materials, but, in addition, the type of motor control and other apparatus has been improved and the arrangement of parts on the car changed until the risk to the patrons of the subways of injury by fire is vanishingly small.

As the general adoption of an idea is good evidence of its merit, it is gratifying to note that both the block-signal train-control system and the steel car, which were developed on the Interborough subway, are steadily being introduced on our trunk-line steam railroads.

In spite of the fact that modern subway cars are covered with detail apparatus, much of which is of an intricate nature, yet as each part is designed for the greatest reliability, the detentions due to equipment failures are astonishingly small and few. The author hopes that there will be contributed at this time some data of that kind, also of maintenance costs, depreciation, etc. It is interesting to note that some of the first Interborough cars, which are nearly 20 years old, are apparently good, from the physical standpoint, for many more years of life.

City-Owned Rapid-Transit Lines in New York

The municipally owned rapid-transit lines of The City of New York are divided, for purposes of operation, into two groups, generally known as Interborough and New York Rapid Transit (also known at various times as Brooklyn Rapid Transit, New York Consolidated, New York Municipal Railway Corporation, and Brooklyn-Manhattan Transit Corporation). The Interborough system of lines (Subway Division) was constructed under three contracts: No. 1, dated February 21, 1900, No. 2, dated July 21, 1902, and No. 3, dated March 19, 1913. The New York Rapid Transit system of subways, together with some elevated lines, was constructed under a single contract, No. 4, dated March 19, 1913, and is operated in conjunction with elevated lines owned by a predecessor company as a single system; the elevated lines of the Manhattan Railway Company, leased to the Interborough Company, are operated independently of the subway division, except in a few places, where trains of both operate over subway-division tracks under a trackageright agreement. The car equipment furnished under contracts Nos. 1 and 2 is the property of the Interborough Company, and that supplied under contracts Nos. 3 and 4 is owned by the city.

Development of the Car Equipment of the Interborough Rapid Transit Company

The story of the car equipment of the Interborough subway is essentially the history of the subway car. The first cars ordered for this road had bodies of a composite type, that is, wood with steel reinforcing and a sheathing of sheet copper, with asbestos

[1] Electrical and Mechanical engineer. Mem. A.S.M.E.

Contributed by Railroad Division for presentation at the Annual Meeting, New York, December 3 to 6, 1923, of The American Society of Mechanical Engineers. Slightly Abridged. All papers subject to revision.

around the wiring for fire protection. The general design of the car was that of a standard passenger coach with enclosed platforms. Motor cars equipped with two 200-hp. motors weighed 76,000 lb. without passengers, and trailer cars 51,300 lb. under like conditions. Before these cars were put in service a design was worked out for an all-steel body and a single experimental car constructed. In this design only standard rolled-steel shapes then on the market were used, so that the weight of the finished car was found to be too great, being 79,200 lb. It is still in service, however, as a pay car. Although little time remained before the opening of the subway, the design was revised, and 300 of these cars were ordered. They weighed 76,925 lb. without passengers, equipped as motor cars. The subway began operation with 103 of these steel cars and 502 composite cars. Express trains consisted of 8 cars—5 motor cars and 3 trailer cars; local trains of 5 cars—3 motor cars and 2 trailer cars. All cars had substantially the same overall dimensions as the latest cars, namely, 51 ft. $^1/_2$ in. long over anti-climber bumpers (51 ft. 4 in. coupling length), 8 ft. 10 in. over door-threshold plates, 8 ft. 8 in. wide over the eaves, and 12 ft. $1^3/_4$ in. high above rail (light). The two motors of the motor cars were mounted on one truck of 80 in. wheel base; the trailer trucks had a wheelbase of 66 in. There were four side doors, one at each corner, so located for convenience of operation by the guard, whose station was between cars; this operation was by mechanical levers which converted a vertical pull or push into a horizontal thrust against the door.

Within a few years after the subway had been put in operation it became congested; one of the measures undertaken after an exhaustive study of possible methods of relief was to add center side doors to the cars. This added an average of 8500 lb. to the weight of a car, but substantially reduced the time at stations for loading and unloading passengers, thereby increasing the train capacity of the stations and the passenger capacity of the subway. These doors were operated by pneumatic door engines, each controlled by a transmission rod extending the whole length of the car with operating handles at the ends, functioning in the same manner as the operating handles for end doors. At this time also the length of the subway-station platforms was increased to suit 10-car express trains (7 motor cars, 3 trailer cars) and 6-car local trains (4 motors, 2 trailers). For those who wish further details of the appearance and dimensions of these cars, a brief bibliography is appended.

In the years 1915 to 1918 the company put into service 800 new steel cars, and also removed all the composite car bodies from the subway, replacing them with steel bodies. (The composite bodies were equipped with new trucks and motors and are in service at present on the Manhattan elevated lines.) These later cars have pneumatic door engines for all side doors. The latest standard motor car weighs 75,500 lb. and the standard trailer 54,000 lb. without passengers. Eighty-three of these cars were specially equipped for operation in the Queensborough (Belmont) tunnels, where the grades are steep, by being provided with two 120-hp. motors per car, it being intended to operate them in trains made up entirely of motor cars. Their weight is 71,800 lb. without passengers. After these changes and additions the subway passenger equipment amounted to 1939 cars, all steel. The rush-hour load is figured at 162 persons per car at 140 lb. each; the total weight of a fully loaded 10-car express train approximates 920,000 lb., and that of a 6-car local train, 550,000 lb. These figures are for the latest type of car, the older cars being heavier.

The general dimensions of the cars, as given above, were fixed in the light of the following limitations:

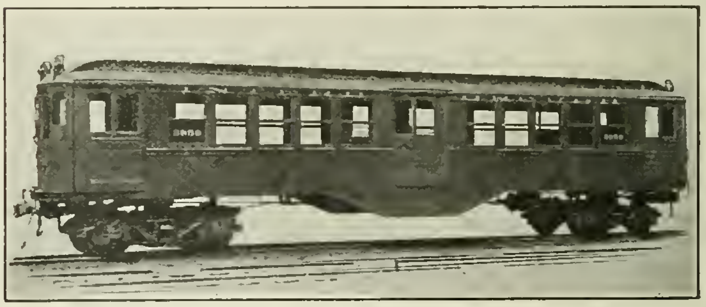
1 Maximum axle load, 30,000 lb.
2 Distance between centers of railroad tracks, 12 ft. 6 in.
3 Maximum height of car above rail, approximately 12 ft.
4 Minimum radius of track curves, 148 ft.
5 Maximum grade 3.1 per cent, except in Queensborough subway tunnels where it is approximately 4.5 per cent
6 Length of station platform: express, 480 ft.; local, 300 ft.
7 Average speed of fully loaded trains between terminal station: express service, 25 miles per hour; local service, 15 miles per hour.

Nearly five years ago, with a view of lowering operating expenses, a scheme of multiple door control was developed to permit a reduction in the number of guards on a train and a shortening of the station stop. The scheme as worked out enables the side doors of an entire train to be controlled by a single guard, although in regular operation one guard is provided for each two cars. The principal changes made in the cars on account of this control were the conversion of the door-engine control from pneumatic to electropneumatic, the introduction of a more sensitive edge or shoe on the doors, and the addition of a considerable amount of wiring and electrical interlocks. These improvements were effected on 982 cars at a cost of nearly $2,000,000. As a result of more than two years' operation of these cars further improvements were developed which are now in course of installation.

Details of the Interborough Company's Latest Car

All of the developments in the Interborough-Company's subway cars are embodied in a group of 100 trailer cars which have just gone into service, and accordingly the following description of these cars may be regarded as representative of the modern subway car.

Body. The body frame is made up of rolled- and pressed-steel members. The floor frame consists of 6-in. I-beams and 6-in. channels, held rigidly in place by liberal cross-braces. Under the center door openings are stiffening girders 26 in. deep. Hedley anti-climbing buffers are fitted at each end. On this underframe is erected a superstructure of pressed-steel side posts and carlines, all carefully braced to insure maximum resistance to shocks caused by buffing or collisions. The end bulkheads also contribute to stiffen the superstructure. The door openings are 4 ft. 2 in. wide, sufficient to allow passengers to pass in and out at the same time. Stanchions of enameled iron pipe located just inside the doors



The Interborough Company's Latest Subway Car

separate and guide the two lines of people. With this arrangement it has been possible to reach an average loading or unloading time of one second per passenger, or less. The roof is of the monitor type with 12 ventilators of the deck sash type per side and is lined with "Agasote," a heat-insulating material. The floor is of $^1/_2$ in. (average) "Flexolith," a light-weight artificial stone. The fixed seats are 44 in number, $18^1/_2$ in. wide. Hinged seats wide enough for two persons are fitted at the center doors to give increased seating capacity if desired. Fifty-six swinging metal handholds with enameled steel grips are installed in each car. Route and destination signs are painted on metal plates and are mounted inside the windows in iron frames. The draft gear is of the friction type, securely attached to the car body. The air connections between cars for the air-brake system are made automatically by the draft gear. Body bolsters are of the built-up type. The air brakes are of the Westinghouse U-E-5 type, with 25-ft. air compressors. Door engines are of the geared type, of sufficient power to close the doors in about two seconds. They are usually adjusted for a closing time of approximately four seconds. The end doors close an opening about 3 ft. wide; they are opened and closed by hand.

Body Electrical Features. Each car has two systems of lighting, the emergency lighting being distinct from the normal. Energy for the normal lights is collected from the third rail by four shoes, one on each side of each truck. Twenty-five lights are provided in each car, two at each platform and the remainder inside the body in three rows, one along the longitudinal center line of the car and the others over the seats. This arrangement produces a minimum illumination of 3 foot-candles on a plane 3 ft. 6 in. above the car floor with a voltage of 85 per cent of the line voltage. The lamps are 40-watt and are shaded. Two emergency lights are supplied, one at each end bulkhead, which are fed from a 34-volt storage battery of Edison cells. The emergency lights are automatically

thrown into service by a relay upon failure of the normal supply. The battery is charged through the normal lighting system.

The cars also have electric fans and electric heaters. There are four ceiling fans per car, each having four blades of the propeller type 38 in. long tip to tip, driven by a 150-volt electric motor at 380 r.p.m., the four motors being connected in series; and 24 heater coils per car, each of 550 watts capacity (divided into three degrees of heat), located under the seats.

As already stated, it is possible for a single guard to control the side doors of an entire train if desired. In such case, by means of a commutating switch mounted under the platform roof the car control circuits are connected to the control bus lines, which are completed between cars by jumpers of the usual type. The jumper heads are unusually large and sturdy for the greatest possible reliability. When the doors are closed, however, no control current passes between cars. The guard is provided with two push-button boxes, each having an opening and a closing button, one box for each side of the train. All doors of a car (on one side) open and close together, except the side end doors of end cars at short station platforms, which doors are specially disconnected from the door-control system. Mechanical locks operated by an air cylinder are pushed into place behind each door when it is closed, to prevent them from opening while the train is in motion. Small lamps are mounted over the center side doors, and do not burn unless all doors are closed and the mechanical locks are in place. Each door is provided with a sensitive door edge enclosed in a sheet-rubber protecting cover, which latter consists of two springs which are forced together if the door edge strikes any obstruction in the door opening. The contact of the two springs completes an electrical circuit in which is included the opening magnet valve of the door engine, causing the door to open at once. The door starts to close again immediately. If the obstruction has not been removed, the opening and closing of the door will be repeated indefinitely. As soon as all side doors are closed and locked, a signal lamp in the motorman's cab burns. This does not require any attention by the guards. A bell cord for passing the starting signal to the motorman is also provided. In general, all wiring is single-conductor, each wire in a separate iron conduit, to prevent leakage of current or crossed wires. A means of opening center doors in case of emergency is provided. By the pulling of a cord inside the car alongside the door the door lock is withdrawn and the door-engine arm thrown off dead center, after which the door may be pushed open.

Subway Car of The New York Rapid Transit Corporation

The motor cars are provided with two motors of the tapped-field type, rated 190 or 200 hp. each, which are of sufficient power to produce an acceleration of a fully loaded train of standard make-up of 1.5 miles per hour per second, and a free running speed of 40 miles per hour (both on a level grade). The multiple-unit control is of the low-voltage type, designed to be operated from a 34-volt battery, and is capable of handling trains of as many as 20 cars.

Trucks. The trucks are all-steel, of the swing-bolster type, with a 66-in. wheelbase and $31^1/_4$-in. wheels, all members being chosen and proportioned to produce a rigid and economical structure. The bolster springs are of the full-elliptic type. Inside-hung brakes are used, proportioned to exert a pressure of 85 per cent of the weight on the wheels. Axles are 6 in. in diameter at the wheel seats, with journals 5 in. by 8 in. Stucki side bearings are provided.

Cars Developed by the New York Rapid Transit Corporation

The New York Municipal Railway Corporation and the New York Consolidated Railroad Company, the predecessors of the New York Rapid Transit Corporation, had no subway cars when contract No. 4 with the city was signed in 1913; hence it was possible to develop a suitable design without the necessity of interchangeability with existing equipment.

The general dimensions of the cars were fixed in accordance with the following limitations:

1 Maximum axle load, 30,000 lb.
2 Distance between centers of railroad tracks, 13 ft.
3 Maximum height of car above rail, approximately 12 ft.
4 Minimum radius of track curves, 125 ft.
5 Maximum grade, approximately 5 per cent
6 Length of station platform: 480 ft. (afterward changed to 530 ft.) at express stations; 300 ft. at local stations
7 Average speed of fully loaded trains between terminal stations: express service, 25 miles per hour; local service, 15 miles per hour.

Interior View of New York Rapid Transit Corporation's Subway Car

After exhaustive studies of all existing types of rapid-transit cars suitable for use in subways, supplemented by original investigation, the engineers of the Railway Corporation decided on an all-steel car 67 ft. long over bumpers (67 ft. $3^1/_2$ in. coupling length), 10 ft. wide over door-threshold plates, (9 ft. $10^{15}/_{16}$ in. over the eaves), and 12 ft. $1^{11}/_{16}$ in. high above the running rails, equipped with two 160-hp. motors and multiple-unit control, and intended to be operated in trains of a maximum of 8 cars. The weight, including the latest modifications, approximates 94,000 lb. without passengers.

Particular attention is called to the door and seating arrangement; it is equivalent to three compartments in line, around all sides of which seats are placed, with a pair of doors on each side of the car at the axis of each compartment. By this arrangement the average distance traveled in the car by a passenger entering or leaving has been reduced to 83.6 in. (calculated value), which may be compared with 87 in., the lowest for other cars of the kind existing in 1913. The seats are of a special contour developed in collaboration with the American Posture League. The seating capacity is 78 in rush hours, but movable seats are provided which may be lowered if desired, the use of which brings the seating capacity up to 90. These cars have carried as many as 300 passengers, seated and standing. Nine hundred of these cars, substantially duplicates, have been delivered on the line, and 50 more are on order. The earlier cars were fully described in the technical press and a brief bibliography of such articles is appended.

The other special features of these cars may perhaps be most conveniently explained by reference to the group of 50 cars above mentioned, now in course of manufacture. These are being equipped as trailer cars, but may be converted into motor cars by adding merely motors and control.

Body. The body is built on a skeleton of rolled and pressed steel. The floor framing consists of two 7-in. and two 8-in. channels

extending the full length of the car, held in place by steel pressings at frequent intervals, the whole forming a rigid structure capable of resisting heavy buffing shocks or the impact of collisions, etc. Hedley anti-climber buffers are provided at each end of the underframe. The side framing consists of pressed-steel posts thoroughly braced; the sheathing is $^3/_{32}$-in. sheet steel. As already stated, there are three pairs of doors per side, each door opening being 32 in. wide. The roof is of the monitor type, with 20 ventilators per side of the deck sash type. The floor is of Flexolith. The seats provide a width of approximately $17^1/_2$ in. per passenger. The route and destination signs are located in the side walls of the cars near the center doors. Two separately adjustable rolls of cloth are provided, one carrying the names of the different routes on the system, the other the names of the different termini of the runs. Three-inch letters are used, which are unusually legible. There are 28 swinging handholds provided in each car in addition to iron-pipe stanchions. All doors, including one at each end of the car, 14 in all, are operated by electropneumatic door engines of the geared type, which are adjusted to close the doors in about three seconds, the limiting rate being under two seconds. The body bolsters, two in number, are of the built-up type. The draft gear is of the friction type, attached to an eye which is framed into and riveted to the car body. The air-brake connections betwen cars are made automatically by the draft gear. The air brakes are Westinghouse electropneumatic, type AMUE. The interior finish is white enamel and light green paint; the exterior finish is dark green. The painting schedule calls for 6 coats. The roof is lined with Agasote. The brake cylinder and accessories, door-control switches, storage battery, etc., are grouped under the center of the car, as usual (and in motor cars the control equipment and air compressor).

Body Electrical Features. There are two systems of lighting in the car, normal and emergency. The normal lights are supplied from the third rail and consist of 20 shaded 56-watt ceiling lamps in three rows, one along the axis of the car and one over each row of side seats. This arrangement of lights produces a minimum illumination of 3 foot-candles on a plane 3 ft. 6 in. above the car floor with 85 per cent of line voltage. The emergency lighting consists of 6 small lamps, supplied with energy from a 32-volt storage battery of Edison cells such as is used for motor and door control. There are several means provided for charging the battery. The emergency lights are automatically switched into service by a relay upon failure of the normal power supply.

The entire car equipment is arranged so that one guard may control the doors of two or more cars. Some of the cars are permanently connected in groups of three, the remainder being single cars capable of being made up into groups of any size. A four-car train usually consists of a three-car unit and a single car, a seven-car train of two three-car units and a single car. Three-car trains are operated by one guard; four-, five- and six-car trains with two guards; seven- and eight-car trains with three guards. The guard's station in a car is between the two center doors, where a push-button control board is provided for his use. In the three-car unit the guard is stationed at the center of the middle car. In these three cars he can open all side doors, open two adjacent end doors to the right of where he is standing, close all doors to his right (side doors), close all side doors to his left, close doors in front of him, close end doors to his right, close end doors to his left. These doors are on one side of the train only; the doors on the opposite side are controlled by a separate button board. These operations are made possible by electrical control of the magnet valves of the door engines, using energy supplied from the 32-volt battery already mentioned. All the doors of a train are provided with interlocks which are connected into a single circuit that is completed through the motor-control circuit of motor cars; it is arranged so that it is impossible to start a train until all doors are closed or within $1^1/_4$ in. of being closed. Thus an obstruction $1^1/_4$ in. wide in the door opening will prevent a clear signal to the motorman. It is impossible to open the doors while the train is in motion. The motorman has a lamp in front of him, which is lighted when all car doors are closed; there is a buzzer signal also which is passed from guard to guard to the motorman for a "proceed" signal in case of temporary failure of the lamp circuit. Push buttons on the outside of the car and also mechanical tripping levers are provided to permit opening doors from outside the car if desired. Inasmuch as there is only one guard to a three-car unit, who stand in the center car, call boxes are provided in the end cars whereby the guard may be summoned in case of need. In order that the guard may announce station names in all cars, loud-speaking telephones (two per car) are installed in the end cars of each three-car unit.

The cars also have electric fans and electric heaters. There are five ceiling fans per car, each having 4 blades of the propeller type 38 in. long tip to tip, driven by a 120-volt electric motor at 380 r.p.m., the five motors being connected in series; and 30 heaters per car, each of 700 watts capacity (divided into three degrees of heat), located under the seats.

One motor is located on each car truck of motor cars; the motors are of the tapped-field type and of sufficient capacity to produce an acceleration of a loaded train (270 passengers per car) of 1.25 miles per hour per second, and a free running speed of 40 miles per hour, both on level grade. The multiple-unit control is of the low-voltage type, designed to be operated from a 32-volt storage battery. It is capable of handling trains of 16 cars, which is twice the maximum length of a train of the present standard. The control circuits are extended from car to car by power-operated commutating switches, known as "slides," built into the car couplers. There is also an empty and load brake attachment, by means of which the motor accelerating current is increased with the passenger load. A 36-ft. air compressor is standard for these cars.

Trucks. The trucks are all-steel, of the swing-bolster type, with an 80-in. wheelbase and 31-in. wheels, with pressed- and rolled-steel side frames, all members being of ample section and securely riveted together. The bolster springs, two in number, are of the full-elliptic type. The brakes are of the clasp type, using malleable-iron shoes, and are proportioned to exert a pressure of 85 per cent of the weight on the wheels. They are equipped with slack adjusters. Axles are $6^1/_2$ in. in diameter at the wheel seats, with journals 5 in. by 9 in. Stucki side bearings are provided. (The wheels of motor trucks are $34^1/_4$ in. and 31 in. in diameter.)

Other Types of Cars. The experience already gained with cars equipped as described above led the engineers of the corporation to make other experiments, two of which are described here.

The first is to be applied to the existing elevated cars, of which the corporation owns more than 900. The wooden bodies are set upon and firmly attached to steel underframes which are coupled together in threes by long drawbars, forming a draft-gear system entirely independent of the car bodies, and one capable of withstanding service shocks and impacts. The bodies are rebuilt to have two doors per side (and no end doors of the unit), both of which are operated by one geared door engine. This engine is of a late type, with a single magnet valve and a differential air piston for control instead of two magnet valves. The guard's station is at the end of a three-car unit instead of in the center of the middle car, as already described for steel cars. One six-car (two-unit) train of this type is in experimental operation.

The second scheme has been developed from certain ideas already on trial in Europe, and is known as the "articulated" train. Four units of this type are substantially as long as eight of the present standard cars. Each unit has a body of three sections articulated together and supported on four trucks. The special features are stated to be no intermediate end doors, location of guard at end of unit, and possibility of more efficient motor control. In the first design wide single side doors are shown instead of pairs of narrower doors, to save space.

BIBLIOGRAPHY

Interborough Rapid-Transit Cars:

American Engineer and Railroad Journal, Oct., 1902, p. 308; Oct., 1904, p. 375.

Street Railway Journal, vol. 20 (1902), p. 382; vol. 21 (1903), pp. 412 and 442; vol. 22 (1903), pp. 237 and 264; vol. 24 (1904), p. 634; vol. 25 (1905), p. 423.

Electric Railway Journal, vol. 31 (1908), p. 6; vol. 33 (1909), pp. 380 and 821; vol. 35 (1910), p. 1057; vol. 45 (1915), pp. 764, 803, and 1124.

New York Rapid-Transit Cars:

Electric Railway Journal, vol. 43 (1914), pp. 1261 and 1327; vol. 44 (1914), p. 1376; vol. 45 (1915), pp. 496, 614, 710, and 872; vol. 57 (1921), p. 1087.

Practically all of the articles listed above are illustrated.

Use of Pulverized Coal in Open-Hearth Furnaces

Comparison of Pulverized Coal with Other Fuels—Its Disadvantages in Open-Hearth Operation—Data on Steel Production with Pulverized Coal and Producer Gas

By R. H. LOWNDES,[1] ATLANTA, GA.

It has been well said that energy is the foundation of industry; therefore it behooves those interested in industry to study closely at all times all the possible phases of the development of energy. There are at most but few sources of energy, three of which are direct and a small number indirect. Further, the three so-called direct sources may all be attributed to but one source. These three are wind, water, and heat. It is not the purpose of this discussion to elaborate on the sources of energy, but rather to pass directly to one specific phase of the last-mentioned source, namely, heat.

Industrial heat energy is obtained by the burning of fuel, which is the bringing together of any two substances that will unite chemically with evolution of heat. Oxygen, one of the most plentiful of substances, is very active chemically, and carbon, the most abundant of all substances, has a strong affinity for oxygen. It is most reasonable, therefore, that these two elements should constitute our chief sources of heat.

Oxygen is of course obtained from the air, and carbon principally from coal. In the burning of coal with air, then, lies the chief source of our heat-derived energy. Our principal effort is to obtain the maximum heat by the best methods of burning. The purpose for which the heat derived is to be used is the principal factor in determining the choice of the method of burning.

Basis of Comparison of Pulverized Coal with Other Fuels

It is the purpose of this paper to discuss specifically the burning of coal in the pulverized state for the production of steel in the open-hearth furnace, and to determine, if possible, whether or not this application is a good one. This can of course be judged only on a basis of comparison with the use of other fuels and other methods of burning. This comparison involves the study of three factors:

1 The cost of the fuel burned, based preferably on the tons of steel output in order to care for the quantity of steel produced

2 The quality of the steel produced, and

3 The consequent cost of repairs and upkeep of the furnace and its accessories.

In considering the first of these factors it is necessary to take into account:

a The cost of coal per ton

b The cost of milling per ton

c The possible losses consequent upon this milling.

By milling is meant the crushing, drying, and pulverizing of the coal and its delivery to the burners along with the necessary air.

Item *a*, the cost of the coal, is always known. Item *b*, the cost of milling, includes several costs which are readily determined. First is the cost of installation of a coal mill, on which investment a reasonable rate of return must be figured. Thus if the coal mill cost, say $25,000, a return of 6 per cent would mean $1500 per year. This divided by the tons of coal milled should be added to the cost of fuel per ton. Also a reasonable sinking fund, reckoned as a percentage of the investment, should be set aside for depreciation and obsolescence; and this, too, should be added to the cost of the fuel. Insurance should likewise be reckoned as an annual expense and charged to the cost of the fuel. Next, the cost of power to drive the mill with its crushers, driers, pulverizers, elevators and conveyors, air compressors and fans; the labor cost, and cost of repairs and upkeep, oil, waste, etc.

The possible losses in fuel value in milling, item *c*, are more difficult to reckon. They are due principally to:

Coal burned to dry the fuel in the drier

Loss in volatile combustible driven off in the process of drying

Loss in leakage of coal dust

Loss in occasional emptying of bins to prevent packing or spontaneous combustion

Loss in fires which occasionally take place.

In considering the second factor, the quality of the steel produced the following items enter:

d The kind of coal used; its constituents other than carbon; the kind and amount of so-called impurities, moisture, volatiles, sulphur, and ash being the chief items. Each of these may affect the steel

e The control of the flame, not only chemically but also as to intensity, direction, shape, and velocity.

The losses enumerated under item *c* are all small, and for a broad discussion need be noted only, and then perhaps discounted. The coal burned to dry the fuel may be neglected since this additional amount is automatically consumed in any method in first driving off the moisture before the available heat in the fuel becomes obtainable. The loss in volatile is apparently quite small. The best available data on this particular point show an average loss of something less than 1 per cent. It seems to be admitted that here is a small loss, but not enough to cause any concern. H. R. Collins, in a paper written in 1918, stated that driers were manufactured which were able to eliminate moisture without distilling any of the volatile combustible matter in the coal. He then described the modern drier, employing temperatures not greater than 300 deg. fahr., and stated that the volatile combustible matter was not likely to be driven off until the temperature rose above 400 deg. fahr.

The loss in coal-dust leakage is purely a mechanical one, and the latest mills have almost entirely stopped this leakage. Until they did so, however, this loss was quite heavy. The loss in having to empty bins is also minimized by increased knowledge of the quantities of fuel necessary in any specific operation, and the consequent prevention of large accumulations in the bins. This same control also minimizes the loss due to fires, and in the modern mill they are almost unknown.

Assuming, then, that coal can be pulverized at a cost of something like 65 cents per ton (J. W. Fuller estimates that coal can be pulverized and delivered to the burners for 35 cents per ton, as compared to 60 cents per ton for gas producers), with coal costing, say, $6.50 per ton, the milling adds about 10 per cent to the cost of the fuel. We have a right to expect this to be returned by virtue of the much-improved burning; and indeed, so far as the heat obtained is concerned, this additional expense is more than justified. This loss is less expensive than the B.t.u. loss in the gas producer. With good burners and proper air adjustment, what may be termed the carburation of the coal dust is so good that the combustion is excellent. Analyses of the products of combustion show the percentage of CO_2 to be very high, in some cases as high as 15.8 per cent. H. R. Collins, of the Fuller Engineering Co., reports tests where this value reached 17 per cent. The excess air necessary is small, only about 18 per cent, and at the very high temperatures reached the sulphur is also largely burned and carried off up the stack as SO_2.

The flame may be directed, lengthened, shortened, made oxidizing or reducing as desired, and the temperature may be kept remarkably constant at any desired point within quite wide ranges.

Disadvantages of Pulverized Coal in Open-Hearth Operation

All of this leads to the belief that pulverized coal is indeed an ideal fuel; for some uses this may be so, but we have not yet considered the third factor in our discussion of open-hearth operation, namely, the cost of repairs and upkeep of the furnace and its accessories. It has been our experience at The Atlantic Steel Company that herein lie the greatest difficulties. We have found the condition of our coal-fired furnace after 100 heats is worse than the condition of a similar furnace, oil-fired, after 287 heats. The

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Presented at the Chattanooga Regional Meeting of the Southern Local Sections of The American Society of Mechanical Engineers, Chattanooga, Tenn., October 23 and 24, 1923.

gas-fired furnaces suffer even less. In round numbers we have got about three times the heats from our other furnaces that we have from the coal-fired furnace, where the refractories cut away, the slag pockets fill faster, and the checkers become choked.

It appears that the excess air carried along with the sweeping flame at the terrific temperature attained so rapidly will attack and cut the refractories more than it does with either the oil or the gas flame. Compared with the gas flame this is not so surprising, but when compared with the oil flame we must seek more closely for a cause of the difference. There are some who attribute the possible cause of the rapid cutting of the refractories with the coal flame to the presence of incandescent ash particles impinging at high temperature in conjunction with the highly heated excess air. This ash, it is supposed, may start some sort of slagging action, which lays the surface of the brick more open to the attack of the oxygen. Certain it is that the ash has a pronounced effect on the slag of the bath. But the chief source of annoyance and expense lies in the deposit of ash as slag in the slag pockets and in the checkers. This takes place very rapidly, and the toughness of the deposited slag is very pronounced. We found that a high stack velocity lessens this deposit materially; but this increase of stack velocity is obtained at the expense of several things. It calls for additional excess air to increase the volume of gases passing so as to increase the velocity. This of course at once reduces the temperature of the flame, but at the same time it increases the cutting effect on the refractories. To carry off this extra volume of flue gas necessitated our passing the gases from the checkers directly to the stack, cutting out the waste-heat boiler. This is of course another serious loss of heat energy. Attempts to use the waste-heat boiler reduced the flue-gas velocity so that the slag deposited very rapidly, and the checkers became badly choked. This choking of the checkers further reduced the gas velocity, which caused a further drop in flame temperature, which in turn seemed to cause more sulphur to enter into combination in the steel. Both the temperature and intensity, as well as the direction of the flame, had to be kept within certain limits to avoid sulphur troubles. It seems that the sulphur oxidizes and passes off as SO_2 at and above certain temperatures. This is doubly advantageous, as the sulphur is not only gotten rid of but it generates heat in burning. When the temperature falls below this critical value the sulphur prefers the iron to the oxygen and goes into the steel, combining in more than one compound. So to get rid of the sulphur the flame intensity should be high, the flame should not be depressed—that is, it should be directed above the bath, and the excess air must be adjusted within narrow limits. Too little excess air and the sulphur is not oxidized; too much, and the temperature drops, and again the sulphur is not oxidized. When these several adjustments are about right to effect a maximum riddance of sulphur, the velocity of the gases is reduced to a point where the refractories cut and the slag deposits heavily.

Cutting off the waste-heat boiler and increasing the excess air increases the flue-gas velocity and lessens the ash and slag deposit; but the refractories cut faster, the temperature of the flame drops, more sulphur enters the bath, and the use of the boiler is entirely lost.

The experience here recounted ran over a period of about seven years, 1916 to 1922, inclusive. These years were seriously affected by war conditions, both high and low peaks being reached in that time. It has been difficult, therefore, to compile any very fair set of data. But the conspicuous and interesting fact is that both study and experience have clearly shown us that the major objections to the use of pulverized coal in the open-hearth furnace lie not in the preparation nor in the burning of the coal, but almost entirely in that part of the work which coal-burning literature touches on so little or not at all, namely, the consequent clean-up, upkeep, and repairs.

There is but one way to correctly evaluate pulverized coal as a fuel for the open-hearth furnace, and that is to watch the industry for a decade or two longer. With the ever-increasing improvements for taking care of difficulties as they present themselves, this type of fuel may indeed come to be more and more used in open-hearth work. But at the present time, it is necessary to state that, the Atlantic Steel Company has just discarded its coal-fired furnace because of the higher cost of producing steel by this means.

Comparative Costs of Open-Hearth Operation with Pulverized Coal and Producer Gas

In Table 1 will be found a few brief figures taken from data accumulated during 1922. This year was chosen as being most nearly representative, since prices of commodities and labor, and of production in general, were then somewhere about midway between the high peak of the war and the low peak of the subsequent depression. These figures show some of the actual costs, and these in turn show why this method of open-hearth operation was abandoned by The Atlantic Steel Company.

TABLE 1 DATA ON STEEL PRODUCTION IN OPEN-HEARTH FURNACES BURNING PULVERIZED COAL—ATLANTIC STEEL CO., 1922

Date	Fuel			Steel			Repairs	
Month	Dollars per ton coal	Dollars per ton coal for milling	Pounds coal per ton steel	Tons steel output	Heats per furnace	Sulphur in steel per cent	Dollars per month	Dollars per ton steel
Apr.	4.83	0.67	668	2271	49		343	0.15
May	4.95	0.60	740	2580	52		771	0.30
June	5.23	0.68	1170	412	9		....	7.28
July	5.40	0.61	580	2453	50		....	1.98
Aug.	6.84	0.60	660	2124	44		1247	0.59
Sept.	7.22	0.82	630	2048	42		1713	0.83
Oct.	7.38	0.56	638	1768	37		3526	2.00
Nov.	7.49	0.52	666	2383	47		3468	1.46
Dec.	8.27	0.58	664	2370	47		1261	0.53
Avg.	$6.40	$0.62	636[1]	2068	42	0.065	$1761	$1.68
Do., for gas[2]	$6.40	$0.60	548	2016	39	0.045	$1361	$0.96

Tennessee coal used, averaging 36 per cent volatile, 53 per cent fixed carbon, $3^1/_2$ per cent moisture, 6 per cent ash, and $1^1/_2$ per cent sulphur.

Dried at an average temperature of 200 deg. fahr., to about 1 per cent moisture.

Average pulverization showing 98 per cent passing 100-mesh screen and $81^1/_2$ per cent passing 200-mesh screen.

[1] This figure obtained by dividing total coal consumption by total steel output.

[2] Average for the same months for two gas-fired furnaces.

It is apparent at a glance from the figures in Table 1 that the gas-made steel is both better and cheaper. It is also apparent that the chief objections to the use of pulverized coal lie in the difficulties engendered in the necessity of running the ash through as a part of the products of combustion.

In a report on Pulverized-Coal Systems in America, compiled by Leonard C. Harvey, and published in London in 1919, under the heading "Opinions of Users" occurs the following statement:

> Have found the average life of checkers for various fuels in the open-hearth furnace to be—
>
> For natural gas............. 1000 heats
> For producer gas............ 350 to 500 heats
> For oil...................... 350 to 500 heats
> For pulverized coal.......... 225 to 250 heats.

This report shows that the Atlantic Steel Company is not alone in its findings as to the life of checkers.

Use of Pulverized Coal in Soaking Pits

The Atlantic Steel Company is continuing its use of pulverized coal in the soaking pits, where the results are far more satisfactory than they were in the furnace, but are not so good as with the producer gas. The slag and ash deposit of course takes place in the combustion chamber, in the soaking pit proper, and at the base of the stack. But this deposit is more readily removed and need never be allowed to accumulate sufficiently to choke the passages. The flame may be made either oxidizing or reducing, and since the steel remains in the solid state the sulphur gives no trouble. For soaking-pit operation the use of pulverized coal appears to be acceptable. We have not used pulverized coal under boilers, except indirectly under the waste-heat boilers from the open-hearth furnace.

It is very interesting to note that in spite of the promising outlook presented by the possibilities in the use of pulverized coal, in actual practice the use of this fuel in open-hearth operation proved with us, as with others, to be unsatisfactory. Nor must it be forgotten that the trouble lay in that part of the operation which is not found in a study of the combustion.

There is reason to hope and to believe that the near future will enable the open-hearth furnaces in small as well as large plants to use pulverized coal as a fuel; but before this can be done there must be some experimenting, and the smaller plants must await the results of these experiments, which only the larger plants can be expected to perform.

SURVEY OF ENGINEERING PROGRESS

A Review of Attainment in Mechanical Engineering and Related Fields

Large Boiler Plants in the United States and Germany

By DR. ING. FRIEDRICH MÜNZINGER

THE author of this book is a director of the Allgemeine Elektricitäts Gesellschaft (A. E. G.) of Berlin, one of the largest electric companies in the world. His knowledge of American conditions is somewhat second-hand, but nevertheless apparently good. It is based on the careful reading of such literature as the Reports of the Prime Movers' Committee of the National Electric Light Association, *Power*, and similar trade publications, and an extensive correspondence with American engineers. His knowledge of German conditions is naturally thorough, as his opportunities for studying them are exceptionally good.

The opinions of such a man as to the comparative methods used in the two countries cannot help being of interest, and the only regret is that enough space is not available to report them more fully.

One feature in American plants that impressed the author is the use of immense boiler units, culminating in the enormous Connelly boilers of the Congress Street Company plant of the Detroit Edison Co.

However, the steam temperatures employed are lower in America than they are in Germany where temperatures at the superheater exit of 350 to 375 deg. cent. (662 to 707 deg. fahr.) are becoming quite common. Economizers are not used to the same extent as in Germany. Considering everything, however, the author comes to the conclusion that American engineers have made extraordinary progress in both the theory and practice of boiler design.

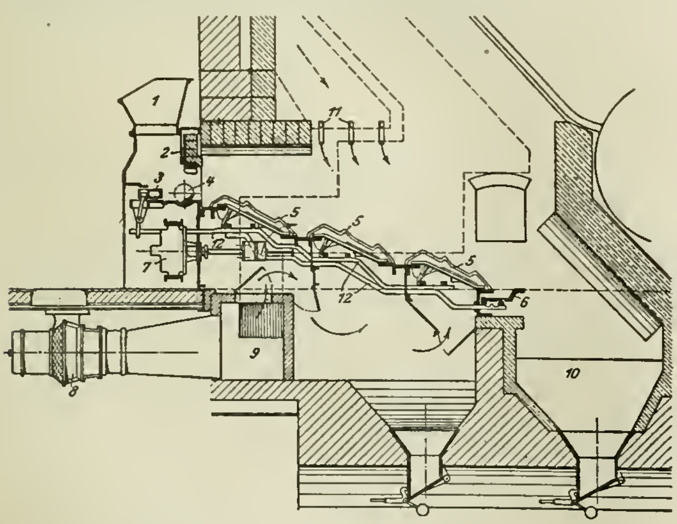


Fig. 1 Kablitz Forced-Draft Stoker

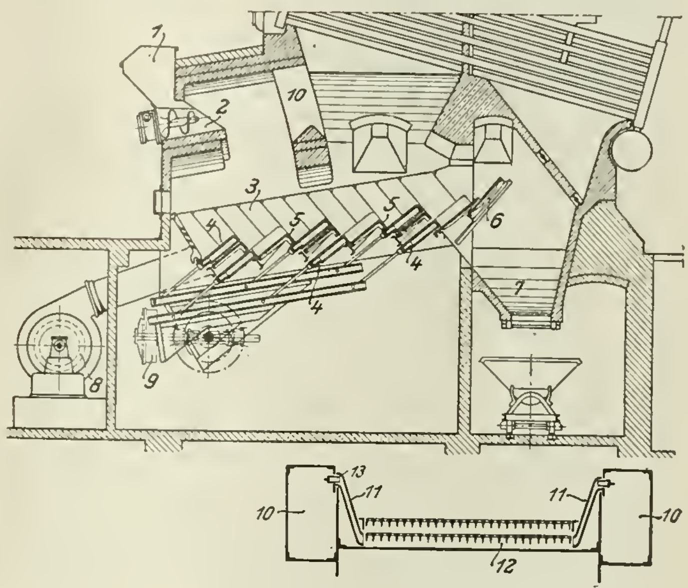
(1, Coal hopper; 2, Coal valve; 3, Forward-motion piston; 4, Rotatable resistance; 5, Grate bars; 6, Ash grate; 7, Grate drive; 8, Forced-draft blower; 9, Forced-draft passage; 10, Ashpit; 11, Admission of secondary air; 12, transfer rods for grate drive.)

Those who are impressed with the highly scientific methods of Europe and think of American practice as rough and ready, may be surprised to hear that in America the use of recording apparatus, such as water meters, temperature and pressure recorders, etc., is far more extensive than in Germany, while the use of systems where all the recording apparatus are concentrated in the operator's cabin, is preëminently American.

As regards stokers, in the larger German power plants the traveling grate is the most usual type for burning ordinary coal. Overfeed stokers are used only sparingly and then preferably for the lower grades of fuel, while underfeed stokers have found practically no market at all. Overfeed grates and stepped grates are used in Germany almost exclusively for low-grade brown coals (a fuel somewhat similar to the American lignites). There are no similar types at all in America, though it is true that increasing attention is being paid to lignite burning in the United States, but only for comparatively high grades of that fuel.

In America grates are very much wider than in Germany, the author mentioning some 7300 mm. (24 ft.) in width; in Germany, however, units wider than 2500 mm. (8.20 ft.) are exceptional, and those of 3000 mm. (9.8 ft.) width are very rare, indeed.

The author believes that the question is not so much how wide the grate surface is as what the heating surface of the boiler should be. If, as in Germany, the heating surface does not exceed 600 to 700 sq. m. (6458 to 7534 sq. ft.) two grates of, say, 2500 mm. (8.20 ft.) wide may be sufficient, this permitting reliable supervision of the entire width of the grate and also the use of poking bars applied through manholes in the brick side walls. When the grates are separated from each other by three or more walls it is impossible to follow clearly what happens in the middle grate, and this will usually affect the efficiency of operation.



Figs. 2 and 3 Vesuvio Grate, Longitudinal and Cross Sections

In Germany overfeed stokers for ordinary coal firing are just beginning to make their way. The Pluto forced-draft stoker is the only one that has found wide application in continental Europe, especially in Austria and Czechoslovakia. Considerable attention has been attracted to the Kablitz forced-draft stoker shown in Fig. 1. The characteristic feature of this type is the presence of the rotatable resistance at the front end and the saw-tooth shape of the grate itself. As a result of the combination of these elements the lower layer of the fuel bed moves over the grate slower than the upper level, this producing at all times a more certain ignition of freshly fed fuel. Every second grate bar is movable. Furthermore, in order to produce a more vigorous stirring action and also to reduce the possibility of bars covered by the fuel burning out, the forward and upward motions take place alternately. As a result of this, most of the time the bars form a smooth surface, thus reducing the chance of the exposed edges of the bars burning away.

Of the two novel methods of burning German brown coal, which, as has been stated, is somewhat similar but not identical with American lignites, may be mentioned the Vesuvio cascade grate (Figs. 2 and 3). On this grate the fuel rests in a trough the bottom of which is formed by the grate bars proper, while the fairly elevated cheeks consist of hollow castings cooled by the forced draft flowing through them. This tends to keep the freely melting slag from clinkering on to these elements. Some of the steplike grate stages are stationary while the stages located ahead and beyond them move contrariwise to each other, i.e., when some go up the others go down. This arrangement of the Vesuvio grate leads to some interesting results which are discussed in detail by the author.

The author discusses next why it is that traveling grates are practically exclusively used in Germany, while in America three fundamentally different types of stokers are employed. This is due not only to technical but also to historical and geographical considerations. Each kind of coal burns especially well on a grate suited to its chemical and physical properties. For example, the nonclinkering coals burn best when the fuel bed is not disturbed, while with clinkering coals some way of shifting the fuel around is of advantage. However, the difference between the various kinds of coal is not distinctly apparent, and in addition to this some one feature of a given coal may be partly overshadowed by the influence of another feature. It is therefore quite possible for stoker manufacturing companies to create a wider market for their types than they are entitled to, and in the opinion of the author this is apparently the case in America.

According to the author, underfeed stokers are preferred in America for coals containing less than 10 to 12 per cent of ash, while traveling grates are used for coals with a higher ash content, the American opinion being that when a low-ash coal is used on traveling grates the rear end of the grate is apt to be covered with a bed that is too thin, thus causing air leakage. Furthermore, it is said that under these conditions, especially with certain coals, the grate, on account of the thin layer of fuel and ash, is apt to be burned out easily when the power demand suddenly falls off or when the furnace is operated with a low fire for a long time. It is a matter of surprise to Dr. Münzinger that a 10 per cent ash content is considered to be the lowest permissible with a traveling grate, as in Germany perfectly satisfactory results are obtained with an ash content of not more than 8 per cent. He does not venture an opinion as to the extent to which this difference is due to the difference in composition of American and German coals outside of ash percentage, or to the difference in the closing devices used at the rear end of the grate. The feature in underfeed stokers that appeals particularly to Americans is their ability to adapt themselves quickly to high peak loads, a matter which, as the author shows elsewhere, is of somewhat less importance in Germany.

Pulverized-Fuel Firing

The author devotes a great deal of attention to American developments in this field. It would appear that in Germany an earnest effort has been made in the same direction during the last three years. Attempts hitherto unsatisfactory have also been made in certain other directions which the author considers as being somewhat hopeless. Thus, an unsuccessful effort was made to burn coarsely pulverized fuel with a grain size from $^1/_2$ to 1 mm. (0.02 to 0.04 in.). The A.E.G. has investigated the burning of finely pulverized coal and has developed a burner. Initially the intention was merely to provide a system of combustion for their own use which would enable them to burn whatever kinds of coal that happen to be available in these days of fuel shortages. These pulverized-coal burners have in the last two years taken care of the greater part of the steam requirements for the two factories of the company and have handled in that time all kinds of coal that were delivered, from Silesian coal rich in ash, to middle German brown coals, coke, semi-coke, anthracite, Brazilian coal rich in sulphur, etc.

The experiences in Germany seem to have led to a belief in the great importance of very fine pulverization and a thorough mixing of the coal with the air. The construction of the pulverized-coal burner of the German company is shown in Fig. 4. In order to effect the uniform mixing of the air and the pulverized coal, this burner contains at the fire end of the worm shaft a conical casting, 5, which scatters the coal dust over its entire surface through the concentrically incoming air and thus produces such a perfect mixture of dust and air that there is no trace of black dust in the flame even directly over the burner exit.

From this point of view Fig. 5 is of interest, in that it shows the distribution of temperatures along the path of the flame in the boiler shown in Fig. 6. It would appear from this that notwithstanding the best possible mixing of coal dust and air, the maximum temperature is reached only at the distance of two meters (6.56 feet) from the burner. Actually, however, even here the combustion is not entirely completed, since directly back of the point of measurement II the flame is being cooled off through radiation to the cold surface which tends to counteract the evolution of heat produced by still further combustion. It would appear that in order to obtain perfect combustion a certain minimum distance has to be provided between the tip of the burner and the water tubes of the boiler, this distance depending on the kind of coal burned. If this distance is too short considerable losses occur through incomplete combustion. The connection between these factors is comparatively little known or considered because a high CO_2 content and an apparently perfect flame may be obtained even where the distance specified above for the development of the flame is insufficient. Where this occurs, however, great losses due to incomplete combustion are inevitable and the content of unconsumed fuel in the ash may run as high as 20 to 40 per cent.

There are other considerations that govern the minimum size of the fire chamber or flame path, meaning by the latter the distance between the tip of the burner and the water tubes. Because of their fine state of pulverization the ashes are carried with the flame and with most coals are apt to fuse together. If these molten ash particles can travel for a sufficient length of time through a zone of temperature lying below their melting point before they

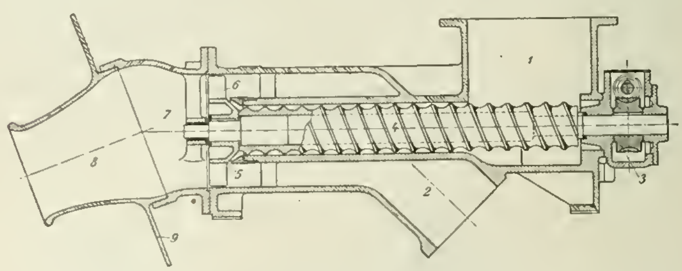


Fig. 4 Pulverized-Coal Burner of the Allgemeine Elektricitaets Gesellschaft

(1, Coal-inlet hopper; 2, Combustion-air inlet; 3, Drive; 4, Worm; 5, Mixing cone; 6, Vane; 7 and 8, Burner orifice.)

reach the cool tubes, they solidify and the iron suboxide contained in the ash is converted by absorption of oxygen into the iron oxide having a much higher melting point. As the author shows, the minimum length of the flame path is therefore determined by two considerations: the necessity for complete combustion of the pulverized fuel, and for solidification and oxidation of the liquefied particles of ash. Unless this is done, slag deposits will form on the water tubes and this will rapidly result in serious disturbances of operation.

Coals rich in gases require, as a rule, a shorter distance or time of flame travel for complete combustion as compared with coals of the anthracite type or those poor in gas. The more graphitic a coal is, the more it requires a long flame path, fine pulverization, and high temperature in the fire room.

As regards the dimensional proportions of the furnace, the conclusions at which the engineers of the A.E.G. have arrived from their experience do not appear to differ in any material way from what is already known in this country.

As regards the general design of modern water-tube boilers, the author believes that the proportioning and arrangement of the water and steam spaces and their connections are capable of improvement. In particular, according to his view not enough attention is paid to the fact that the dimensions of these parts depend not only on the size of the boiler but also on the specific load on its heating area. As regards certain American water-tube boilers, he is of the opinion that their designers still have ahead of them the solution of problems which have already been solved in Germany

and he is not surprised at the frequent complaints about insufficient or irregular superheating, priming, etc.

German practice has shown it to be entirely possible to build water-tube boilers in such a manner that even at very high loads they will deliver dry steam, and that the superheat will be maintained practically uniform within a wide variation of load. When superheating is irregular the fault practically always lies in improper proportioning of the cross-sections through which the water and steam circulate or of the steam and water spaces, although occasionally this may be due to an excessive content of salts in the water. Since the beginning of the war no new boiler types have been placed on the German market, but a great deal of attention has been paid to the improvement of boilers of the old types. In this direction material assistance has been lent by the research work conducted by the Association of Large Boiler Owners, and dealing especially with selection and testing of materials of construction and riveting and building of the drums. As a result of these efforts all riveted seams not absolutely necessary have been eliminated and seamless drums are now used in preference to riveted ones.

Superheaters and Economizers

The first point that the author stresses in this connection is that in America, and differing from German practice, superheaters and stokers as a rule are not built by the boiler manufacturers. As a result there are a large number of superheaters on the market, and those fitted to particular boilers do not always work well with them. He points out that superheat temperature regulators built

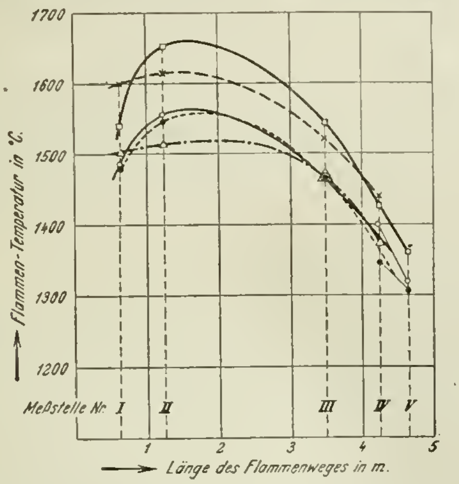


Fig. 5 Temperature Distribution in the Flame of the Burner Shown in Fig. 4 with Various Kinds of Coal and Under Various Conditions of Combustion

(Ordinates: Flame temperatures in deg. cent. Abscissas: length of flame in meter; *Messstelle* = point of measurement.)

into the upper drum of the boiler are practically unknown in America. With all their advantages they have the disadvantage that they make access to the water tubes more difficult, and that in large power plants a change of temperature requires an adjustment of a large number of regulators. A German company has brought out a central temperature regulator which is built into the main steam-supply line and regulates the temperature of steam as delivered by an entire battery of boilers. It works on the same principle as the regulator built into a steam drum, i.e., a variable part of the superheated steam is led through a pipe surrounded by water and cooled therein. The steam developed from the cooling water is then supplied to the boiler or steam pipe. Regulation of steam temperature is particularly important in the case of large turbines where excessive temperature (above the safe limit) may cause considerable trouble, and where such an excess occurs quite frequently unless proper provision for temperature regulation is made.

Economizers are not used in America to the same extent as in Germany, and even in the latter country the relative costs of production of economizers and boilers are beginning to approach American conditions. The author points out an increase in use of economizers in this country, in particular those made of wrought iron, a practice which has been of decreasing frequency in Germany since 1916.

With cast-iron economizers the pressures in America vary between 11 and 24 atmos., the usual pressures not exceeding 18 atmos. (255 lb. per sq. in.). A German company has developed a novel type of economizer which it is claimed may be safely operated at pressures up to 80 atmos. (1136 lb. per sq. in.), this being due to the use of a construction which prevents the stripping of the economizer tubes.

Air Preheating

The author devotes a considerable amount of space to the subject of preheating the air, which he says is arousing a great deal of

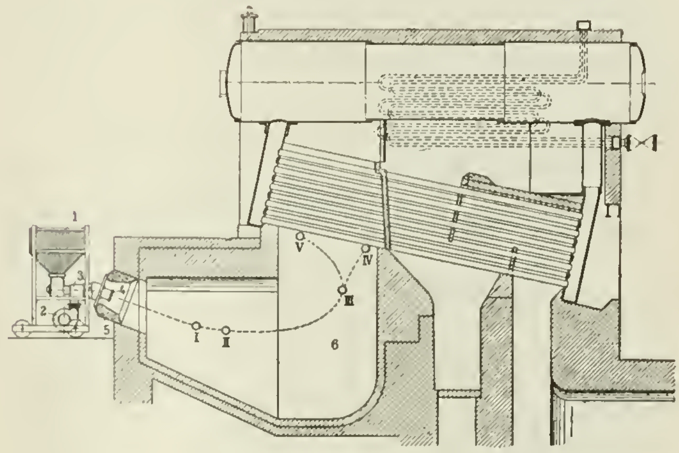


Fig. 6 Boiler Used in Experiments from Which Curves of Fig. 5 are Derived

(Old type, 200 sq. m. heating surface.)

interest both in Germany and in America. In Germany air preheaters have been used on shipboard and have given good results, but as far as the author is aware, they have not been installed in any of the more important German plants.

There is a certain element of competition between the air preheater and economizer, and the question which one of the two is preferable should not be considered from a thermodynamic point of view exclusively. It is perfectly possible, of course, to install an air preheater behind an economizer and in some cases improve the efficiency by a few per cent. The advisability of this procedure, however, depends on whether the combined depreciation, interest, and maintenance costs of the air preheater are enough less than the savings in fuel cost. Furthermore, the complication of the plant and increased possibilities of trouble must be considered.

Nevertheless it would be wrong to assume that air preheaters have no economic justification in connection with large stationary boilers. In plants where feedwater has a temperature 60 to 70 deg. cent. (140 to 158 deg. fahr.) or higher, where the load on the boilers varies greatly, where it is desirable to increase the steam output of available boilers, and particularly where the fuel is of such a character that it will burn better with warm air, air preheaters are justified and will rapidly pay for themselves. There is also a good chance for air preheaters in connection with pulverized-coal firing or where hot air is used for drying. Thus, for example, air preheaters prove to be valuable in Indian sugar factories where bagasse is used as fuel.

One of the main reasons why air preheaters have been so little adopted heretofore is, in the opinion of the author, that no data are available as to the extent to which grate operation and the efficiency of firing are improved by the use of preheated air and also to what extent the furnace temperature increases with air preheating. He attempts to answer this last question by analytical calculation.

An interesting chapter in the original book—not suitable for abstracting owing to lack of space—is devoted to the subject of heat accumulators, such as the Ruths steam accumulator, in connection with which a special type of turbine, the so-called oscillating turbine, has been developed, its particular feature being that the high- and low-pressure sides never work at the same time. (*Amerikanische und deutsche Grossdampfkessel*, by Dr. Ing. Friedrich Münzinger, 178 pp., 181 figs., *cdA*. Published in Berlin, 1923, by Verlag von Julius Springer.)

Short Abstracts of the Month

AIR ENGINEERING (See Special Processes)

ENGINEERING MATERIALS (See also Machine Parts)

Monel Metal at High Temperatures

Monel Metal for High-Temperature Work. This article reproduces curves (Fig. 1) obtained from G. & J. Weir, Cathcart, Glasgow, Scotland, showing the ultimate tensile strength of monel metal at varying temperatures, in addition to which curves from an article published in a previous issue of the same journal (April, 1923,

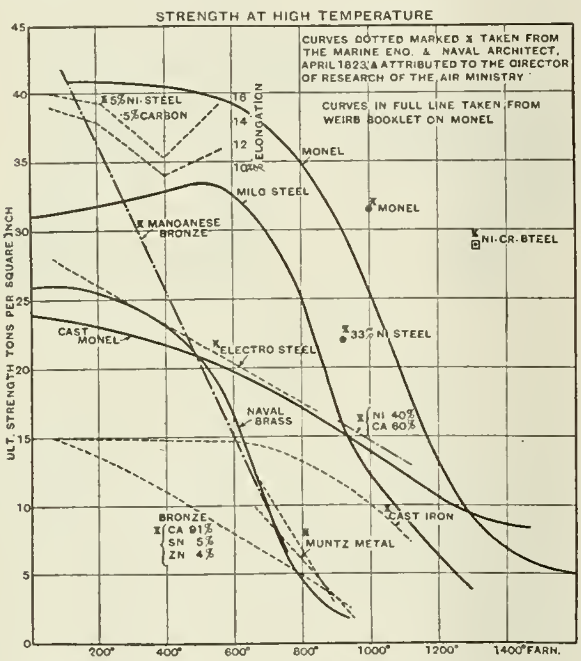


Fig. 1 Tensile Strength of Various Metals at High Temperatures

p. 125) are reproduced for purposes of comparison. From these curves it would appear that at 700 deg. cent. (371.1 deg. fahr.) monel is stronger than wire steel, manganese bronze, or naval brass. (*Marine Engineer and Naval Architect*, vol. 46, no. 551, Aug., 1923, p. 303, 2 figs., *d*)

Stainless Steels from the Point of View of the Glass Industry, W. H. Hatfield. Stainless steel maintains its strength at high temperatures to a much greater degree than ordinary structural steel. Thus at 800 deg. cent. structural carbon steel has a tensile strength of four tons and stainless steel one of over six and a half tons. In comparison with ordinary carbon steel and even alloy steels and tungsten steels, stainless steel shows a greater resistance to scaling with increasing temperature. A clean metallic surface is, however, necessary for the best rust-resisting results, though it is not necessary to have a highly polished surface provided all scale and pit marks are eliminated. (*Journal of the Society of Glass Technology*, vol. 7, no. 26, June, 1923, pp. 142–148 and 3 photomicrographs, discussion pp. 149–153, *dp*)

Manufacture of Pearlitic Gray Cast Iron in the Electric Furnace. Of late considerable attention has been attracted to the so-called pearlitic cast iron developed in Germany. In pearlitic cast iron the usual structure of ferrite and carbon in flake form is replaced by a structure where the carbon is in a somewhat more finely divided form, and instead of ferrite a mixture of ferrite and pearlite is encountered. This result is obtained first by giving the iron a strictly controlled chemical content. Thus, it is stated that the total carbon must be between 3 and 3.1 per cent, silicon in the region of 1.5 per cent, and the manganese content 0.7 to 0.8 per cent. The next condition is the casting in a fairly hot mold at a temperature of the order of 400 deg. fahr.

The present article gives general data on this material which has physical properties far superior to ordinary cast iron, and, in particular, describes the manufacturing methods used at the works of Brown, Boveri & Co., in Baden, Switzerland. (Translation of article by Dr. H. Frei in *Die Giesserei*, July 12, 1923. *Foundry Trade Journal*, vol. 28, no. 363, Aug. 2, 1923, pp. 95–96, 4 figs., *d*)

Effect of Low-Temperature Annealing on Some Mechanical Properties of Cold-Drawn Steels, S. H. Rees. As a result of cold drawing without subsequent annealing a considerable increase takes place in the value of the yield/tensile strength ratio and also in the value of the yield point both in tension and compression.

The directional effect of the cold drawing is marked in the case of the high-carbon steel tested.

The effect of low-temperature annealing on the maximum load and yield point in the case of the mild steel and stainless iron is not appreciable, but they do not decrease in value until the material is annealed above 300 deg. cent.

The elastic limit in all cases is greatly improved by low-temperature annealing.

The directional effect of the cold work is probably a function of the original hardness of the steel and the amount of cold working. It is very noticeable in the values obtained with high-carbon steel, but with other steels it is not so apparent, although in no instance does the elastic limit in compression quite reach the figure attained in tension.

The elastic range is not a constant value in the materials investigated, and from the results given it would seem that the mechanical properties of all cold-worked steels are improved by a low-temperature treatment. (Paper before the September, 1923 meeting of the *Iron and Steel Institute*, abstracted from advance proof, 11 pp., 8 figs., *p*)

FOUNDRY (See Special Processes)

FUELS AND FIRING (See also Gas Producers)

The Utilization of Coke Breeze. Description of practice at the plant of the Bradford Road Gas Works, Manchester, England, which is equipped for the complete mechanical handling and burning of coke breeze under steam boilers, and for the mechanical handling of the resulting ash and clinker. The breeze arrives by overhead telpher conveyor, and from that time to when the cooled and quenched ash and clinker are dumped into carts for conveyance to the tips, the material is never touched by hand.

A good sample of coke breeze will contain about 10 per cent water, 20 to 25 per cent ash, about 65 per cent fixed carbon, and about $2^3/_4$ per cent volatile matter. This will have a heating value of between 9000 to 10,000 B.t.u. per lb. Much breeze, however, contains 20 to 25 per cent water, which materially reduces the heating value and efficiency of the fuel.

Coke breeze is a difficult fuel to burn because of its low quality and fine state of division, the latter being apt to cause great loss by unburned fuel falling through the grate. Another trouble is the large amount of flue dust formed, partly because of the mechanical condition of the fuel, and partly due to the steam-jet forced draft, which tends to blow the material off the fire bars. The consequence is that the flues soon become choked with dust, and have to be cleaned out every six to eight weeks instead of every six to twelve months as with ordinary coal. For these reasons mechanical stoking and water-tube boilers give far more efficient results with breeze.

An Underfeed impelled-draft traveling-grate stoker is used in this instance. The stoker consists of an endless moving chain, heavy box-shaped fire bars mounted on driving chains connected in the usual way to sprocket wheels attached to the driving shaft, and special driving mechanism at the front of the stoker. These transverse box-shaped fire bars are composed of heavy framework, containing inside a number of small fire bars, so that the whole of the slow-moving grate surface consists of a very large number of

these small fire bars with a very widely distributed air supply, and it is practically impossible for any coke breeze to fall through the grate.

The driving mechanism gives eight variations in the speed of travel of the grate. The power is taken from a short motor-driven overhead driving shaft running at about 70 r.p.m., and is extraordinarily small, not more than $^1/_3$ hp. The coke-breeze feed mechanism from the hoppers in front of the stokers is regulated, as usual, by means of a vertical sliding gate raised or lowered by a rack and pinion; and, by varying the speed of the stoker and the air supply, the amount of coke breeze burned per square foot of grate area per hour is as high as 50 lb.

The forced-draft air supply is obtained from two small electrically driven forced-draft fans built into special casing at each end of the fuel hoppers, thus causing the cold air from the fire hole to be taken in through the fans and delivered through trunking to a wind box at each end of the stoker, means being provided for varying the air so that different amounts of air are allowed to pass into the fuel bed at different lengths of the grate according to the thickness of the fuel bed.

The automatic ash-removal plant is of the Usco patent sluicing system. In this the hot ash and clinker as it comes continuously over the end of the stoker falls into a trough, through which is flowing constantly a stream of water about 3 in. deep, the width of the trough being 21 in. The mass of ash and clinker is quenched at once and swept along in the stream of water in the trough, and is discharged into a large concrete sump in the ground alongside the boiler plant. This sump is 12 ft. by 12 ft. by 15 ft. deep. (*The Gas World*, vol. 79, no. 2037, Aug. 4, 1923, pp. 90–91, *d*)

Froth Flotation as Applied to Coal, C. H. S. Tupholme. Description of two recent developments intended to render the concentrates from the froth-flotation system of coal washing more suitable for industrial purposes. These developments deal with ways to separate the coal particles from the associated water.

In the first method the froth-flotation concentrates or other powdered-coal particles associated with water are suspended in sufficient water to make a mobile pulp. This pulp is then subjected to agitation, usually with aeration. To this is added an oil, tar, and some other hydrocarbon or carbonaceous liquid which has the property of coating the coal particles and also of causing the coal particles coated to flocculate together, after which the coated and flocculated particles are separated from the water by draining or filtration without being compressed into blocks or briquets.

The removal of water from the coated and flocculated particles may be assisted by pressure. However, it must be remembered that the coating and flocculating agent does not act as a binder and therefore will not suffice as a binding medium in the manufacture of briquets.

This method offers particular advantages when the coal particles are subsequently to be made into coke, because the hydrocarbons in the flocculating agent are distilled in the coking operation and may therefore be recovered. Moreover, the presence of these hydrocarbons in the mass of the flocculated coal particles constitutes an addition of volatile matter which assists the coking of special types of coal, which would otherwise be unsuitable for the manufacture of coke.

The article gives data of tests which would indicate the effectiveness of the process. However, it does not appear quite clearly as to whether it has yet reached the stage where it can be applied on a commercial scale. (*Coal Age*, vol. 24, no. 8, Aug. 23, 1923, pp. 277–278, *dA*)

The Tempering of Coal, Thos. A. Marsh, Mem. A.S.M.E. The author comes to the following conclusions:

1 Moisture can be added to some coals to definite advantage. This applies to western bituminous coals. (Pittsburgh and west.)

2 Coke breeze, anthracite, and dock screenings burn better when slightly dampened to prevent siftings and blowing of the fuel bed.

3 The effects of moistening are more pronounced on traveling-grate stokers so far as combustion results are concerned.

4 The amount of moisture to be added will average about 3 per cent, which is equivalent to 0.3 per cent decrease in net evaporative effect from the coal.

5 The advantages obtained from tempering coal more than offset the slight decrease in net value of the coal.

6 Steam and hot water temper coal quickly and well but should be used only when a study of gain and loss has been made.

7 Tempering requires time. Cold water added in stoker hoppers does not temper coal.

8 Moisture should be added with discretion and under guidance of some tests to indicate amounts and effect of various items of the heat balance. (*Association of Iron and Steel Electrical Engineers*, vol. 5, no. 9, Sept., 1923, pp. 369–379, 4 figs., *p*)

GAS PRODUCERS (See also Special Processes)

History and Present Practice of the Ash-Fusion Type of Gas Producer

The Ash-Fusion Type of Gas Producer, E. Servais. The main disadvantages of the conventional type of gas producer lie in the comparatively small output per unit and the high content of carbon dioxide in the gas generated. Furthermore, the cost of operation is comparatively high and the producer requires careful and skilled attention.

The development of the ash-fusion type of producer dates back to the work of a Frenchman, Ebelmen, who built a small unit in 1841. This producer ran on charcoal and gave comparatively good results. The experiments were, however, brought to a premature conclusion by the death of the inventor.

In 1906 Fichet and Huertay, the first named being a relative of Ebelmen, took up the same problem using coal instead of charcoal as fuel. Very serious difficulties arose, however, and they never succeeded in making the unit run regularly. In the same year Victor Sépulchre, a Belgian engineer, built an ash-fusion-type producer quite similar to that of Ebelmen and ran it on local lignites. With this fuel, which gave very poor results in a Siemens-type producer, Sépulchre secured excellent operation. In fact, a battery of six producers of his type ran for many years until the local beds of lignite were exhausted.

Fichet and Huertay entered into a coöperative arrangement with Sépulchre and in 1910 enlisted the interest of a large steel company, the Société d'Ougrée-Marihaye, which placed a cupola in one of its plants at their disposal. The cupola was transformed into a gas producer, the present author taking part in this work, and the results of the initial tests were so encouraging that in 1913 two large units were installed in Germany, two other units being installed later and bringing the production up to a gasification of 200 tons in 24 hr.

The main dimensions of these producers were as follows:

Hearth:	Inside diameter.......	1.600 m.	(63 in.)
	Height...............	1.800 m.	(70.86 in.)
Boshes:	Height...............	1.200 m.	(47.25 in.)
Trough:	Inside diameter.......	2.800 m.	(110.25 in.)
	Height...............	2.300 m.	(90.50 in.)
Total height of apparatus.......		5.300 m.	(208.75 in.)

The brickwork, 35 cm. (14 in.) thick, consisted of blast-furnace-type brick in a sheet-iron frame. Two tap holes were located at the hearth level, 1.5 m. (59 in.) above which were set eight tuyeres made of bronze, water-cooled and connected to a circular air conduit.

The charging device with double closure was placed on the roof of the gas producer and had a capacity of 1 cu.m. (35.31 cu. ft.). There were two diametrically opposite gas outlets leading through parallel conduits to a large gas-holder chamber on top of which was placed an air preheater consisting of a bundle of tubes through which the gas passed, the air flowing on the outside of these tubes. The blast was supplied by two Roots blowers of 2000 hp. capacity each with an output of 200 cu.m. (7062 cu. ft.) per min. at a pressure of 1.200 m. (47.25 in.) of water, the air output being governed by valves.

The fuel used in this case was Ruhr coke varying in size from 10 to 60 mm. (0.4 to 2.4 in.) and containing from 12 to 15 per cent of ash and water. The ash analyzed on the average as follows: SiO_2, 48 per cent; Al_2O_3, 36 per cent; Fe_2O_3, 9 per cent; CaO, 3 per cent; varia, 4 per cent.

The problem was to determine whether the ash-fusion-type gas producer would be made capable of burning fuels other than special lignites.

In the early part of the experimental work considerable difficulty was encountered. The producer ran perfectly well for a few hours at the beginning, the output of gas being plentiful and the gas of high value. There was no trouble with the slag, but at the end of 15 hr. the tuyeres became coated with heavy layers of dense deposits which no effort succeeded in dislodging. Gradually the sticky mass invaded the whole interior of the gas producer, the blast pressure had to be increased, the output of gas fell off, and the slag refused to run out. It then became necessary to stop and clean the producer, not an attractive job as the mass formed inside was very hard.

An analysis of conditions of operation and processes inside the gas producer led to the belief that the trouble was due to premature melting of the slags and coke ashes. As a matter of fact, simple calculation would indicate that the temperature resulting from the conversion into carbon monoxide of 75 per cent of carbon mixed with 25 per cent of inert matter must exceed 1600 deg. cent. (2912 deg. fahr.).

This temperature, under the conditions of operation then prevailing, was rapidly reached in the zone of the tuyeres. It extended progressively to the upper layers and made the ashes sticky. The charge was interfered with in its downward movement and the air blast encountered coke mixed with pasty slag, trouble resulting.

In the blast furnace, where some of the conditions of operation are very similar to those of the ash-fusion-type gas producer, this kind of trouble is not encountered as a rule because the excess of heat developed by the combustion of fuel is absorbed in the reduction of the ore. This led to the conclusion that it was necessary to make the gas producer similar to the blast furnace in this respect by giving it something to reduce, and water vapor was selected for this purpose, partly because it was easy to regulate the amount of its admission and also because the hydrogen produced by dissociation would tend to increase the heating value of the gas.

With this in mind a series of tubes connected to a steam pipe were placed 50 cm. (20 in.) above the blast tuyeres. The results were very satisfactory. The temperature of the ascending current of gases was lowered by the decomposition of the water vapor and the upper layers of the fuel bed ceased to grow pasty. This process was patented in Germany. Gas analysis served as a basis for determining the amount of vapor that had to be injected. In actual practice the following procedure is used: After the producer has been started up, the steam valve is gradually opened until the content of carbon dioxide in the gas reaches from $1^1/_2$ to 2 per cent. It has been found that under these conditions the steam is practically entirely decomposed, the preliminary fusion of the slag eliminated, and the heating value of the gas brought up to maximum. The dissociation of the steam absorbs approximately one-third of the heat developed by the combustion of the coke and the gas shows the following composition having a heating value of 1140 to 1200 cal.: Carbon monoxide, 31 to 32 per cent; H_2, 6 to 8 per cent; carbon dioxide 1.5 to 2 per cent; N_2, 58 to 60 per cent.

This analysis was obtained with coke as fuel, and obviously a different composition of gas would be obtained with fuel containing volatile constituents.

As soon as the part played by the injection of steam and the method of using it have been established, it becomes fairly easy to determine by trial the proper blast pressure, the diameter of the tuyeres, and the thickness of the bed necessary to secure the best operation of the producer. The following are the results which the author claims to have obtained: The quantity of coke gasified in 24 hr. was from 50 to 55 metric tons (55 to 60.5 short tons); this may be lowered to 35 metric tons (38.5 short tons) without trouble, but if the output is reduced still further the flow of slag becomes excessively sluggish. The normal operation apparently corresponds to a combustion of 1100 kg. of coke per hr. per sq. meter of surface of the hearth (225 lb. per sq. ft.).

At first broken limestone was added as flux, but when the lumps were of a certain size not enough time was available for them to act with the silica in the slags and they were usually found at the bottom of the cupola. Because of this granulated blast-furnace slag was tried having the following composition: SiO_2, 30 per cent; Al_2O_3, 15 per cent; CaO, 42 per cent; MgO, 6 per cent; Fe_2O_3 and MnO, 7 per cent.

It is not enough, however, to add the quantities theoretically necessary to obtain with the slags a product fusible at the temperature prevailing in the fuel bed; it proved to be necessary to add quantities up to 10 or 12 per cent of the weight of the fuel, this excess being necessary to produce a sufficient quantity of heat in the hearth part of the furnace, the gas producer not having a metallic bath with a large reserve of heat like the blast furnace.

Analysis of the slag formed in the producer showed it to have the following average composition: SiO_2, 38 per cent; Al_2O_3, 26 per cent; CaO, 32 per cent; MgO, 2 per cent; Fe_2O_3, 1 per cent; and MnO, 1 per cent. This slag comes out with a temperature of 1500 to 1600 deg. cent. (2732 to 2912 deg. fahr.) and gives a very light product on granulation. In addition to the slag, there issues a highly silicious pig iron from the iron contained in the ashes and flux.

Later on the blast-furnace slag was replaced by slag coming from the producer itself to which was added finely broken limestone, the purpose of which was to maintain a constant composition of the fuel bed. The air of combustion is blown in through eight tuyeres under a pressure of 800 to 1000 mm. (31.5 to 39.37 in.) of water and a temperature of about 250 deg. cent. (482 deg. fahr.). The heating of the air is not absolutely necessary, at least for some fuels, and one of the later installations made by the author has operated for several months with cold air. The author found, however, that the tapping of the slag, which is a good deal colder with cold air blast, is apt to give trouble once in a while, and that it is of advantage to heat the air to as high a temperature as possible. The heat brought in by the hot air increases the temperature in the zone of fusion and hence the temperature of the slag; it also permits the injection of more water vapor, thus increasing the heating value of the gas. This again results in a higher efficiency where the gases are not used directly as they leave the gas producer. The sensible heat of the gases, which on issuing from the producer have a temperature of 550 to 800 deg. cent. (1022 to 1472 deg. fahr.) in accordance with the humidity and the physical properties of the coke, may be employed to preheat the air, as the author has done in the majority of his installations, and may also be used to generate steam for injection purposes.

As regards dust content of the gas, it is much higher than that obtained in slow-running producers, but the quantities of dust are not very large where the fuels and flux used do not themselves contain large amounts of dust. In general, there was no trouble in cleaning a gas until it contained not more than 0.02 gram per cu. m. (0.0087 grains per cu. ft.) of dust.

The operation of the gas producer is cheap and very simple. It is limited to charging the fuel every 12 to 15 min. and tapping the slag every 2 hr. It is not necessary to clean the walls as the fuel does not stick to them. The maintenance charges are limited to repairs of the hearth and boshes once every six to eight months. The renewal of the brickwork takes about a week. The trough lining lasts for years.

The author gives a heat balance of the ash-fusion producers from which he derives a thermal efficiency of 77 per cent. He claims to have obtained these results with Ruhr coke in installations gasifying up to 70 metric tons (77 short tons) per unit.

In the discussion which followed M. Hock pointed out that the great value of the ash-fusion gas producer lies in its ability to handle not only fuels with a very high content of ash but fuel containing materials which hitherto have not been really considered as fuels at all. Another advantage of this procedure is its continuous operation. (Paper before the Scientific Congress of the Association of Engineering Alumni of the Liège School, abstracted through *Revue Universelle des Mines*, 6th series, vol. 18, no. 4, Aug. 15, 1923, pp. 251–260, *dA*)

[Ash from most coals contains small amounts of iron as shown by the production of pig iron from ash-fusion gas producers mentioned in the paper of Servais abstracted above. This fact is taken advantage of in a recently developed process of recovery of unconsumed fuel from ashes by magnetic separation (Germany). It appears that as a result of chemical conditions in the fuel bed the iron is present in the ash in the form of magnetic oxide and the ash and cinders are attracted by the magnets of the separator while the unconsumed fuel is not.—Editor.]

INTERNAL-COMBUSTION ENGINEERING (See Marine Engineering)

A Water-Cooled Internal-Combustion Turbine

The Puplett Internal-Combustion Turbine. Description of a turbine invented by T. Puplett, of Manchester, England, in which the difficulty of keeping the parts from overheating is said to be solved by a system of water cooling.

Briefly, the Puplett turbine consists of a heavy cylindrical casing very thoroughly water-jacketed. This casing is held between two water-jacketed side plates drawn together by bolts. Also held between the side plates are two iron rings pierced by inclined ports, and in the narrow space between these rings is a third ring, also ported, and free to rotate through a small angle.

Inside this assembly of rings runs the rotor, a cast-iron wheel 12 in. in diameter with vanes on its periphery. The rotor shaft, of course, is carried in bearings in the end plates.

It will be seen that this construction gives an assembly as follows: an outer casing, an annular space, a fixed ring of ports, a movable ring of ports, another fixed ring of ports, and, finally, a vaned wheel or rotor. The annular space is the combustion chamber, and it may be put into communication with the rotor vanes, or cut off therefrom, by altering the positions of the port rings.

The combustion chamber is charged with gas drawn into a separate pump cylinder operated by suitable gearing from the rotor shaft. Valves in the turbine back plate allow the pump piston to transfer its charge and compress it into the annular combustion chamber, where it is ignited in the ordinary way by a sparking plug.

At one point of the combustion-chamber wall is a tangentially disposed cylinder which contains a small spring-loaded plunger, connected by a link to a lug on the movable port ring. The expansion of the gas drives the plunger outward, so moving the ring and putting all three rings of ports in the same relative position that the gas is free to pass through and impinge upon the rotor vanes. By a timed eccentric motion the plunger returns when the next charge is ready.

The gas, after doing its main work upon the rotor vanes, finds its way through exhaust holes drilled through the rotor rim toward the center, which is recessed. These exhaust holes are drilled in such a manner as to take advantage of whatever velocity remains in the gas. Holes are drilled in the web of the rotor, and the exhaust gas escapes through ports in either one or both of the side plates of the machine. Exhaust gas is prevented from reaching the shaft by spring-loaded rings carried in grooves in the rotor boss, which is also drilled parallel with the shaft axis so that air can circulate.

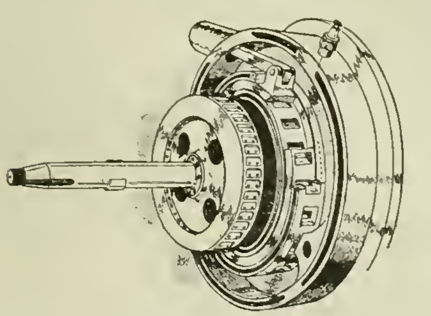


Fig. 2 Puplett Internal-Combustion Turbine. Part Sectional View Showing the Three Rings of Ports and the Rotor

(The middle ring of ports is movable and is controlled by a spring-loaded plunger in a small cylinder set at a tangent to the casing.)

Naturally, the internal heat of this machine would quickly render it unworkable unless special precautions were taken. The water jacketing of the outer casing and end plates presents no difficulty, and the problem is the cooling of the enclosed ports. This is done very simply by putting an annular groove in each edge of the two fixed port rings and then drilling through from one side to the other in the solid metal between every port. There are fifteen ports and fifteen water spaces, therefore, in each ring.

Oil grooves are machined on the contact faces of the port rings, and lubrication may be by oil spray from the combustion-chamber walls, by ducts through the end plates, or by admixture of oil with the gasoline. The port-ring movement, however, is very slight, and there are no other parts requiring lubrication except the shaft bearings, which are fed from oil holes in the shaft.

The turbine is intended to be worked in tandem, two or more complete units on the one shaft, so that there shall be no noticeable unevenness of torque due to the "dead" intervals while the combustion chamber is being charged. In the smaller sizes, at any rate, it is intended that the charging cylinder shall be annular and located between each turbine unit, the piston being coaxial with the shaft. In bigger plants a separate compressor, driven from the main shaft, would be used. (*The Autocar*, vol. 51, no. 1452, Aug. 17, 1923, p. 281, 1 fig., *d*)

The Revolver-Type Internal-Combustion Engine

The Revolver-Type Engine. Description of a French design which constitutes a revival of a comparatively old idea.

The revolver-type engine was tried unsuccessfully in France ten years ago. Recently, however, Edouard Laage, an aviator, produced such an engine of 300 hp. with 16 cylinders arranged in two horizontally opposed rings of eight each. The arrangement of the cylinders is similar to the magazine of a revolver and it is possible to make the engine either as a rotary unit or with the cylinders stationary.

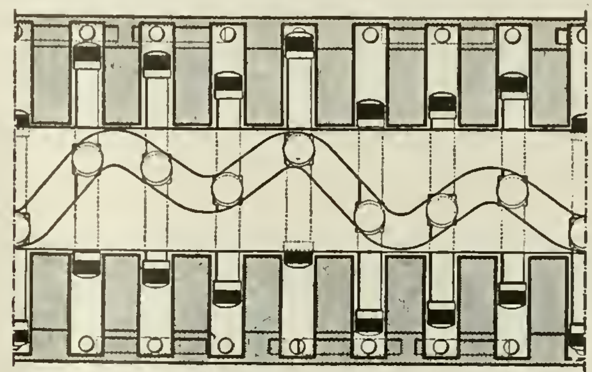


Fig. 3 Development Diagram of Cam Path, Showing the Cycle of Operations Which is Completed in One Revolution

(From left to right the cycle of operations shown in the diagram is as follows for the top line of cylinders: induction, compression, power stroke, exhaust, scavenging. The same series occurs in the opposed cylinders.)

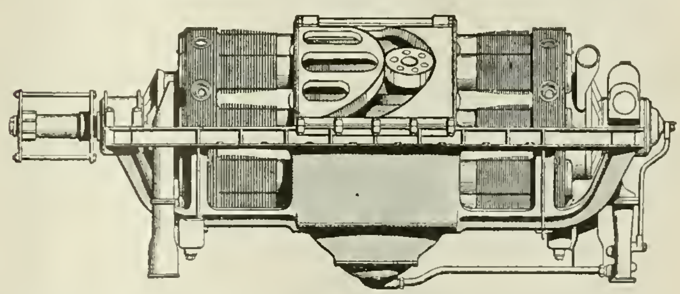


Fig. 4 General View of Engine, with Top Half of Cover Removed, Showing One of the Rollers Which Travel in the Stationary Cam Path

(Each pair of horizontally opposed cylinders acts on this cam path through connected pistons and rollers)

The relative reciprocating movement of cylinders with pistons (Fig. 3) is secured by a kind of double cam cut right around the cylindrical portion of the engine which joins the two sets of horizontally opposed cylinders and might be called a crankcase but for the fact that it has no cranks inside it. In the sinuous path thus formed rollers are constrained to travel, there being a pair of these for each pair of horizontally opposed cylinders.

There is one very important point which should now be noticed. The sinuous track in which the rollers work, and which imparts movements of reciprocation to the pistons in the cylinders, can be formed in any way that may be desired, whereas with the ordinary crank and connecting-rod arrangement the only variation that can be obtained in the cycle of operations is the small one that can be secured by offsetting the crankshaft. In the revolver type, however, any desired cycle of piston movement can be obtained simply by varying the form of the path which the rollers follow, and in the example that has been constructed in France a six-stroke cycle has been adopted between exhaust and induction. The induction and compression strokes are only half the length of the subsequent power stroke, so that the utmost advantage is taken of expansion—an advantage analogous to that of the compound steam engine over the

simple. (*The Autocar*, vol. 51, no. 1450, Aug. 3, 1923, p. 189, 2 figs., *d*)

MACHINE PARTS

Research on Ball Bearings, H. G. Freeland. The author formulates a series of questions on ball bearings and gives answers to them. From these questions it would appear that the cause of failure of bearings is more often to be found in the races than in the balls, and that the inner race is more susceptible to failure than the outer.

The cause of ball failure in at least 90 per cent of the cases is to be found in surface defects, such as seams, most of which originate in the steel mills. There are no steel mills which can as yet supply on a commercial basis drawn wire rod or hot-rolled stock entirely free from such defects as rolling laps, seams, decarburization, etc. The process of manufacture of balls is of less importance than the freedom of the steel from defects, particularly those on or near the surface. The author considers pressed and forged balls superior to turned balls.

It does not appear that any reduction of size takes place as a result of operation of balls if free from dirt and correctly lubricated. (*Automotive Industries*, vol. 49, no. 8, Aug. 23, 1923, pp. 368–369, *gp*)

Steel Conveyor Belt at a Stone-Pulverizing Plant, Geo. M. Earnshaw. Data on an installation of the Waukesha Lime & Stone Co. at Waukesha, Wis., in which a steel conveyor connects the crushing and pulverizing plants and special bin gates are provided for feeding the stone to it in the crushing plant.

The belt is of 178 ft. centers, is 16 in. wide and 0.035 in. thick. Because of the exactness required in jointing the belt, the installation was carried out by the Sandvik Steel Service Department. The joint is, however, a common lap fastened together by countersunk rivets.

At present the belt handles the product of one pulverator which gives 30 tons per hour. Plans have been drawn up for the installation of a second pulverator which will double the output. Because of the fact that the rate of delivery per hour at the discharge end is governed by the maximum capacity of the pulverator while the length of the belt is fixed, a speed of 100 ft. per min. had to be used. This speed is, however, a very slow speed for these belts to operate, the usual speed being 200 ft. per min., while in some installations 300 ft. per min. has been found possible. Because of this, when the second pulverator is installed the carrying capacity of the belt can be doubled by merely changing the driving pulley.

According to the statement of the manager of the plant, the belt is free from vibration, runs flat, requires less power than other belts in the plant carrying less material, and has never given any trouble.

According to author, who is associate editor of *Rock Products*, there are now in existence three steel-belt installations in rock-product plants: namely, the one already described, one at the Michigan Portland Cement Co., Chelsea, Mich., and the one at Penn-Allen Cement Co., Penn Allen, Pa. (*Rock Products*, vol. 26, no. 17, Aug. 25, 1923, pp. 37–40, 11 figs., *d*)

MARINE ENGINEERING

Cost of Converting a Steamship to Diesel Power

Cost of Converting to Diesel Power an 8000-Ton Shipping Board Ship, Louis R. Ford, Mem. A.S.M.E. A discussion of the probable cost of conversion of one class of Shipping Board vessels. Only some of the features can be reported here.

In considering this question of power, it should be borne in mind that a Diesel engine will sustain its rated power continuously, day after day, whereas a steam plant is subject to wide variations and seldom maintains its designed power for very long intervals. This means that on the average voyage it is not necessary that the rated Diesel power be as great as the rated steam power to enable a vessel to complete the voyage in the same length of time. When converting a 10-knot vessel with 2500 steam hp., a 2000-b.hp. Diesel engine, which would drive the ship a 9.2 knots, should be sufficient if equal results as to time of passage on moderately long voyages is desired. If a special machinery arrangement such as Diesel-electric drive or geared drive is desired, dimensional limitations will have less influence in deciding the horsepower that can be used. For the purposes of this discussion, we will assume that a 2000-b.hp. four-cycle engine is to be used, direct-connected to the propeller shaft.

The next step is to consider the type, number, and size of auxiliaries to be used. One of the most vexing questions involved in the consideration of a conversion job is whether the steam deck winches shall be retained or be replaced by electric winches. From the operating point of view unquestionable the most satisfactory arrangement is to completely eliminate all steam auxiliaries throughout the vessel. Electrically operated auxiliaries have become standardized to the extent that today steam auxiliaries on a motorship are about as acceptable as tan shoes with a dress suit, and no one would consider building a new general-cargo motorship without electrical auxiliaries.

On account of consideration of investment cost and fixed charges it may be desirable to retain the steam cargo winches already available on the ships. Since sufficient boiler power to operate the deck winches must be available and since such auxiliaries as steam-driven condenser circulating pump; boiler-feed pump; boiler oil-feed pumps, sanitary pumps, fresh-water pumps, fire and bilge pumps, and electric-lighting generators are also available, it may be desirable to retain the steam drive for all of them, though electrically operated auxiliaries may be more economical.

A good compromise may be arrived at by installing electrically operated engine-room auxiliaries and an electrically operated steering engine for use at sea, with sufficient Diesel-electric generator capacity to furnish them with current, and retain such of the existing steam auxiliaries as are needed for operation in port. With this arrangement the operating procedure would be to allow steam to die out at sea and operate the ship purely as a motorship with electric auxiliaries, and, upon arrival in port, raise steam in the boiler and shut down both the main and auxiliary Diesel engines. The auxiliary air compressor should be steam-driven. A reduction in first cost is thus obtained, and ample assurance against breakdown is provided. The only time this auxiliary compressor will be required for pumping up starting air is when entering or leaving port or shifting berth, at which times the boiler will be under steam. The principal classification societies have ruled that such a steam-operated compressor arrangement will be approved by them.

The boiler system is discussed next and it is proposed to retain one of the existing boilers, provided it is in good condition, and utilize for the heating of living quarters a small steam boiler through which the exhaust gases from the engine may be passed when necessary.

The article gives a tabulation of the equipment to be retained and new equipment to be purchased, the latter amounting to $213,078, which is, by the way, several times the price of the unconverted vessel if bought from the Shipping Board.

Assuming that the steamer may be purchased from the Shipping Board for $6 per deadweight ton, one can now estimate the total cost of conversion to a motorship as follows:

Cost of steamer	$ 52,800.00
Cost of new machinery	213,078.00
Cost of shipyard work	80,000.00
Total cost of conversion	$345,878.00
Cost per deadweight ton	$39 to $40

Since the low price level of good steamers is about $30 per deadweight ton, and for European-built motorships probably not less than $60, it would seem that the converted Shipping Board vessel at $40 per deadweight ton should be in an advantageous position in competition with either. Its superior fuel economy should more than overcome the steamer's advantage in fixed charges, and in comparison with the European motorship its smaller fixed charges should overcome the latter's advantage as regards operating costs.

The original article contains two figures—one showing the engine-room machinery arrangement for a conversion plan in which no steam auxiliaries are used, and the other the compromise arrangement whereby steam auxiliaries may be used in port and only electric auxiliaries at sea. (*Motorship*, vol. 8, no. 9, Sept., 1923, pp. 620–623 and 649, 2 figs., *p*)

MEASURING INSTRUMENTS

The Recording Ultramicrometer, John J. Dowling. Description of an apparatus based on an electric-valve method for measuring small capacity variations and which differs in principle from a similar apparatus developed by Professor Whiddington and described in Mechanical Engineering, vol. 43, Jan., 1921, p. 49. It is claimed that the apparatus under consideration is less complicated, in addition to which it permits recording measurements which Whiddington's apparatus does not.

The article describes in detail the electrical features involved in the design of the apparatus. This part cannot be abstracted because of lack of space.

The recording ultramicrometer may be applied to the determination of minute displacements, changes of length, and the like, and it is claimed that no very delicate adjustments need be provided for the condenser plates. An important application of the device is in the construction of an extensimeter. According to Ewing, it is desirable with an 8-in. specimen to read the extension within one fifty-thousandth of an inch or to within two-millionths of a centimeter per centimeter length. With the present apparatus this amount can be easily recorded on a specimen even 1 in. long, and furthermore the lateral strain may also be recorded and thus may be determined Poisson's ratio and hence all the elastic constants on even quite small specimens.

The apparatus responds to rapid variations of the observed phenomena. The author describes the use of the device to record minute flexure of the diaphragm of a pressure gage in which it gave some unusually interesting results. (*London, Edinburgh and Dublin Philosophical Magazine and Journal of Science*, vol. 46, no. 271, July, 1923, pp. 81–100, 9 figs., *dA*)

METALLURGY (See Engineering Materials; Special Processes)

MOTOR-CAR ENGINEERING

The Lagonda Car. One of the unique features in the construction of this car is the chassis, or rather lack of it in the usually accepted sense of the term. The pressed-steel members of the body take the load of the engine and transmission gear and are mounted directly on the springs, which are designed especially for the job. Quarter-elliptic rear springs and a specially designed transverse front spring support the vehicle on the road wheels, and as regards the front transverse spring a special arrangement of linkage and anchorage is designed which effectually does away with any tendency to rolling.

The oil for the shaft, big ends, little ends, and the exhaust and inlet valve gears is circulated by a rotary pump driven off the camshaft. This is a new development and takes the place of the outside plunger pump driven by a disk and crankpin which was fitted to the previous model. It makes a neater and a more effective arrangement, and one quite immune from any possibility of derangement.

The oil is lifted from a strainer chamber in the sump and delivered under pressure to the main bearings direct and to the overhead valve motion, the side camshaft, and the silent-chain distribution gear.

Troughs are arranged in the under part of the aluminum crankcase, into which the big ends of the connecting rods dip. These troughs are kept supplied by the pump, and dippers on the big ends not only insure adequate lubrication of these important bearings, but also splash up the oil for the cylinder walls and little ends. A lead running from the pump takes the oil up to the rocker arms above the inlet valves and lubricates the rocker and push-rod mechanism.

It will be seen, therefore, that the lubrication system is automatic and self-contained. The overhead inlet valve gear is fully protected and enclosed, and the leakage of oil prevented by the well-fitting and very neat aluminum cover which encloses it, and which can be quickly and easily removed by undoing the two wing nuts which hold it down on its oil-tight sealing joint. (*Auto-Motor Journal*, vol. 28, no. 32/1179, Aug. 9, 1923, pp. 661–664, 10 figs., *d*)

POWER-PLANT ENGINEERING

Reduction of Leaving Losses in Steam Turbines

Devices to Reduce Leaving Losses in Steam Turbines, Ivor R. Cox. The author briefly discusses the theory underlying the difficulty with losses in the last row of blades. This is well known and therefore is not abstracted.

The first and obvious method of obtaining greater leaving area is by increasing the mean diameter of the last stage without decreasing the height of the last row of blades. The question of excessive stresses and vibration puts a limit in this direction, however.

Instead of the parallel blade, another way is to use a blade the section of which is larger at the root than at the tip, such as taper blades or blades widened toward the root. By suitable thickening and widening o the blades and without increasing stresses it is possible to increase the leaving area by approximately one hundred per cent.

The author shows a design where increased leaving area is obtained by the use of a very large disk in the last stage but at the expense of the safety in this stage. With turbines of the reaction type the double-flow arrangement may help. With the two-cylinder design (cylinders arranged in tandem) which is now practically standard in England for axial-flow reaction turbines of large outputs, the low-pressure cylinder only is made double-flow.

Another way of obtaining increased leaving area is by having more than one "last row" of blades without departing from the single-cylinder design. One of the earliest arrangements of that kind, illustrated in the original article, was devised by Delaporte, who suggested the use of two condensers.

A part of the steam flowing through the turbine is taken to the first condenser from immediately before the last stage, the vacuum in this condenser being relatively low. The remainder of the steam flows through the last stage and exhausts to the second condenser, in which a high vacuum is maintained. The circulating water flows first through the condenser giving the higher vacuums, and then through the other, the primary object of the invention being to obtain increased output with the same quantity and temperature of circulating water. The arrangement is, in addition, well suited to reduce leaving losses when these are high, as the steam velocity leaving the last row of blades is much reduced owing to the reduction in steam quantity consequent on exhausting a portion of the steam at the last stage but one to a second condenser, the vacuum of which may be arranged to correspond with the required design pressure in front of the last stage.

Another illustration shows a type of exhaust end with a continental design of turbine, the double-flow arrangement being employed in the last stage only. This arrangement is not described as it has obvious disadvantages.

A third method for obtaining double leaving area without reversing the general axial direction of flow of steam is contained in Guy's British patent (No. 14596, year 1915). Here, near the last stage, by means of a specially shaped diaphragm, steam is diverted into two annular portions. There are two similar "last stages" through which the steam is exhausted to the condenser in parallel streams. It is of course also possible to divide the steam into two portions earlier in the expansion.

From this the author proceeds to the description of the multi-exhaust construction invented by Baumann (compare Mechanical Engineering, vol. 45, no. 7, July, 1923, pp. 430–431).

The use of a diffuser for decreasing leaving losses, which was at one time fairly common, particularly with radial-flow machines, has fallen into disuse as the actual improvement in steam consumption is small.

In recent years feed heating by extracting low-pressure steam from the turbine has proved beneficial in improving the economy in power-station work, and the author discusses this feature of design in some detail. He claims that feed heating also acts as a device for reducing leaving losses.

A certain amount of steam is bled at, say, a low-pressure stage for feed-heating purposes. This steam does not therefore pass through the last stage of the turbine, the leaving velocity is thereby lowered, and the leaving losses decreased. In a particular case, with a 10,000-kw. turbine, the leaving and exhaust loss, when working without feed heating, is 4 per cent. By tapping a low-

pressure stage the feedwater temperature is brought up from, say, 70 deg. to 170 deg. fahr. The approximate reduction in steam quantity passing through the last stage is some 8 per cent, so that the leaving and exhaust loss is reduced by 15 per cent, which is equivalent to a gain of approximately 0.6 per cent on the overall turbine efficiency. When the feedwater is raised to a higher temperature than in this example, the reduction in leaving and exhaust loss is still more. Thus, in a particular case known to the writer, the final feed temperature is 300 deg. fahr., the decrease in steam quantity flowing through the turbine exhaust, as compared with no feed heating, is 20 per cent, and the decrease in leaving and exhaust loss no less than 35 per cent.

The other loss occasioned at the exhaust end of the turbine is that due to the velocity of the steam through the actual exhaust passage. This loss, in general, is small compared with the leaving loss, as it is comparatively easy to provide a reasonably large exhaust area. For maximum efficiency the steam should travel by easy paths properly guided from the last row, or rows, of blades to the condenser. In such an exhaust it can be taken that the loss, as measured by the drop in pressure, is equal to the head corresponding to the exhaust velocity. We have seen that the leaving loss L is given by

$$L = \frac{V^2}{2\,gJ}$$

Similarly the exhaust loss E is given by

$$E = \frac{X^2}{2\,gJ}$$

where X = steam velocity in the turbine exhaust, i.e.,

$$E \text{ (expressed as a percentage)} = \left(\frac{X}{224}\right)^2 \times \frac{100}{i}$$

$$\therefore L + E = \frac{100}{i}\left\{\left(\frac{V}{224}\right)^2 + \left(\frac{X}{224}\right)^2\right\}$$

$$= \frac{100}{i}\left(\frac{Z}{224}\right)^2$$

where Z is that velocity which gives the same total loss as the leaving loss and the exhaust loss.

This enables us to deal with the combined leaving and exhaust losses by imagining an area called the "equivalent exhaust area," which is such an area that the steam at exhaust pressure flowing through it would occasion a loss equal to the sum of the leaving and exhaust losses. Thus, if A_z = equivalent exhaust area, A_v = leaving area, and A_x = exhaust area, as $V^2 + X^2 = Z^2$,

$$\therefore \frac{1}{A^2_v} + \frac{1}{A^2_x} = \frac{1}{A^2_z}$$

The use of the equivalent exhaust area enables a comparison to be made quickly between differently designed turbines of a given output used under similar steam conditions. (*Beama*, vol. 13, no. 65, Sept., 1923, pp. 175–181, 6 figs., *dc*)

PUMPS

Motor-Operated Centrifugal Pumps in Steel Plants, R. A. Cornwell. In the steel industry one of the most important factors in maintaining production is the efficiency and reliability of the water-supply system. Centrifugal pumps are extensively used and the author considers here the operation of motor-driven pumps as compared with steam-turbine-driven pumps.

As regards cost, it would appear that when delivering water at the rate of 1,250,000 gal. per hr. the cost of pumping 1000 gal. of water per hr. is \$0.00238. For the same condition the cost of pumping water by a steam-turbine-driven pump is \$0.00288. Similar comparisons are given for the installation costs.

From this the author proceeds to an extended discussion of types of motors for driving centrifugal pumps and some of the features of the electrical installation. (*Association of Iron and Steel Electrical Engineers*, vol. 5, no. 9, Sept., 1923, vol. 309–326, 6 figs., *cp*)

RAILROAD ENGINEERING

The Development of the Continuous Turntable, Otis E. Hovey, Mem. A.S.M.E. A brief criticism of existing types and description of a new design developed by the American Bridge Company.

In this new type the main girders are continuous from end to end and are provided with top and bottom laterals. These main girders are made shallow so that irregularity in the upper surface of the circle rail should not cause material increase in the girder stresses. The attachment of the end trucks to the main girder is so arranged that the reinforced end webs of the main girders rest upon heavy bearing plates on the trucks; furthermore, the arrangement is such that the truck can rock with respect to the girders, thus permitting the wheels to take equal loads from the girders. The entire train of driving mechanism and the brake are mounted on the truck frame.

One of the drawings shows a roller type of center recommended for use under continuous tables, it being claimed that it is more efficient than the usual disk type. The general advantages of continuous type are discussed in detail. (*Railway Age*, vol. 75, no. 7, Aug. 18, 1923, pp. 295–298, 7 figs., *dc*)

REFRIGERATING ENGINEERING (See Testing and Measurements)

SPECIAL PROCESSES

Use of Conditioned and Enriched Air in Gas Producers, Cupolas, and Blast Furnaces

The Use of Preheated, Dry, Moist and Oxygen-Enriched Air in Gas Producers, Cupolas and Blast Furnaces, J. Seigle. The conditions of operation in ordinary furnaces and the three types of apparatus mentioned in the title are radically different in each case. In furnaces the desire is to achieve complete combustion at the required high temperature without inordinate excess of air. In gas producers the aim is to increase the potential heat of the gas and at the same time decrease the heat evolved in the apparatus itself. In cupolas it is to reduce the potential heat in the flue gas so that it will contain as much carbon dioxide as possible and only a little carbon monoxide; furthermore, an effort is made to cause as large an amount of sensible heat to develop in the apparatus as possible, which serves to raise the temperature of the metal and to insure cool gas in the flue. In blast furnaces the aim is roughly the same as in cupolas, namely, to have a gas in the flue with a low potential heat and low sensible heat; to burn as much as possible of the carbon to carbon dioxide in the apparatus, etc.

From this it would appear that the aim of the combustion process in cupolas and blast furnaces is exactly opposite to that in gas producers, so that what would make for good efficiency in one case would be undesirable in another. From this point of view it is rather curious to find that the same means, such as air preheating, air drying or moistening, and oxygen enrichment have been suggested for all three classes of apparatus, i.e., boiler furnaces, gas producers, cupolas and blast furnaces, although the aims of the processes are radically different.

The author discusses the possibility of improvement by these means for each type. In apparatus like boiler furnaces he finds that preheated air improves operation in several ways. For gas producers dried air may be left out of consideration, as a certain amount of water vapor has long been known to improve operation, in particular by making it more regular. Recently Servais at the Metallurgical Congress in Liège mentioned the advantages of the use of water vapor in air in gas producers of the ash-fusion type, where the injection of water vapor prevented clinkering of the bed which otherwise tended to become excessive. In the Mond process water vapor is used to increase the ammonia content in the gas, and finally in the water-gas producer it is an essential element of the process.

Preheating of air has been used in several types of gas producers. It has been particularly useful in ash-fusion-type producers and it has been found, among other things, that the use of preheated air results in the lowering of the temperature of the gas, as a result of which more calories are available in the form of potential heat of

the gas. It would appear that air preheating is very useful in the case of producers.

The author shows by figures that it may be also worth while to use preheated air and water vapor simultaneously.

Oxygen-enriched air has been tried in producers but is not used commercially as yet, the reason probably being that the advantages obtained do not compensate for the higher cost of the process. It is possible that enriched air may be used instead of preheated air in ash-fusion-type producers.

As regards cupolas, the usual process is to use room air. There does not appear to be any good reason to expect material improvement from dry air, and obviously it would be inadvisable to make special additions of water vapor to the air. As far as the author is aware, no attempt has been made to use enriched air, because the advantages are not likely to compensate for the higher cost of the process. Preheated air has been tried, but under ordinary foundry conditions did not give valuable results. It has been found of value in cases where particularly high temperatures of melting were desired, as, for example, in Rollet cupolas for making specially pure iron or in cupolas melting ferrochrome.

In blast furnaces the use of preheated air is well known and the author gives numerical data in this connection. As regards dry air, he refers to Gayley's work, but expresses the opinion that where preheated air is used the additional cost of air drying does not produce improvements sufficient to compensate for it. He discusses to some extent oxygen-enriched air on the basis of the tests at the Ougree plant and gives some interesting data, among other things showing a comparison of the characteristics of exhaust gas from blast furnaces working with ordinary preheated air and with oxygen-enriched air. (*Revue de Métallurgie*, vol. 20, no. 7, July, 1923, pp. 481–489, 1 fig., *ep*)

TESTING AND MEASUREMENTS

New Stroboscopic Instrument for Studying High-Speed Motion. Description of an optical instrument called the Rotostat, which is in principle a motor-driven stroboscope. A hood, fitting the face, is provided, in the front of which is an aperture eclipsed by a pierced shutter. The latter is motor-driven and its speed is controlled by the turning of two knobs, one for coarse and the other for fine adjustments. When the speeds of the shutter and the observed object are exactly equal, the latter appears to stand still. When the shutter runs faster or slower, the object appears to move at a rate equal to the difference in speeds. The apparatus works from a 110-volt lighting circuit and the entire manipulation consists merely of turning the knobs until the desired object speed is obtained. (*Automotive Industries*, vol. 49, no. 11, Sept. 13, 1923, p. 521, 1 fig., *d*)

Reliability of Fluid Meters in Refrigerating Tests, L. S. Morse. Data of calibration of a number of meters, from which it would appear that they often give incorrect readings.

The table in the original article shows, for example, the percentage of error of the venturi meter compared with the calibrated receivers. This meter was ordered for flows of from 20 to 35 cu. ft. per hr., corresponding to about 750 to 1310 lb. per hr., but the scale which the manufacturers sent for the manometer was graduated from zero to 5000 lb. The dimensions on the lower part of the scale were very close together and there was but one division $^1/_4$ in. long from 0 to 500 lb. Consequently any flows below 500 lb. per hr. could not be accurately determined, which accounts for the large errors at these low tonnages where less than 500 lb. was used.

A smaller venturi tube and scale has recently been ordered and with its use it is expected that the error will be reduced for these lower flows.

In the discussion C. H. Smoot, Mem. A.S.M.E., called attention to the fact that The American Society of Mechanical Engineers is contemplating a code involving the use of nozzles for the measurement of fluids and gave some information on this subject. He also criticized, to a certain extent, the method of testing used by the author of the paper in that the fluid meter was used to measure a flow of fluid that was not steady, a purpose for which it is not designed.

Clemens Herschel, the inventor of the venturi water meter, defended the use of this instrument, both by the fact of its extensive use for more than thirty years and by direct proofs such as data contained in paper No. 1744 of The American Society of Mechanical Engineers. He also attacked the methods of computation and calibration used by the author. The other discussions of Mr. Morse's paper, though of interest, cannot be abstracted here owing to lack of space. (*Refrigerating Engineering*, vol. 10, no. 1, July, 1923, original paper pp. 1–10, 5 figs., and discussion pp. 8 and 10–13, *ee*)

THERMODYNAMICS

Specific Heats of Gases and Vapors, Aimé Witz. Extensive article giving the history of the investigation of specific heats of gases and a comparison of the values obtained by various investigators, together with a theoretical consideration of the main features of the variation of specific heat with temperature.

The general conclusion to which the author, who is a corresponding member of the French Institute, comes is that the variations of the capacities with temperatures are due primarily to intermolecular work. This conclusion follows in the most direct manner from the fact that the capacity of the monatomic vapor of mercury and of rare gases is independent of the temperature. This has been indicated to a certain extent by the experiments of Pier.

Recent development of the mechanical theory of heat has made it possible to formulate certain hypotheses regarding the properties of gases which appear to be dependent on the nature and constitution of the molecule. This latter, however, is extremely complicated and comparatively little is known about it. The author discusses in particular the data provided by the kinetic theory of gases.

The recent hypotheses dealing with molecular reactions may permit penetrating more deeply into this matter. Already a more complete analysis of phenomena has been made by taking into consideration the degrees of freedom of molecules in their movements of translation, vibration, and rotation, and in addition to this new avenues for research have been opened by the theory of quanta. Bjerrum, Krüger, and others have already entered into this new promising field of research.

In this connection the author calls attention to certain views expressed by Berthelot. From a comparison of the true specific heat of water vapor or carbon dioxide with the heats of their elements, and the fact that there is found at 2000 deg. cent. (3632 deg. fahr.) a notable excess of the former, Berthelot came to the conclusion that this excess of specific heat is due to the existence of a double work.

First there is the work of molecular disaggregation of the composite fluid not accompanied by any change in its chemical composition; this is followed by the work of chemical decomposition correlative to dissociation. The first work corresponds to an increase in potential energy which may be attributed to a change in the number of molecules not accompanied by decomposition (as apparently occurs in chlorine), or to some phenomenon analogous to a dispersion of the constituent parts of the chemical molecules. Berthelot compares this effect to that which precedes the rupture of a metal wire subjected to an increasing tensile stress. This work would permit an explanation of the decrease of the heat of formation of the compound at the higher temperatures. (The heat of formation of water, equal to 58,700 cal. at zero, falls off to 37,100 cal. at 4000 deg. cent. (7232 deg. fahr.).)

In citing the views of Berthelot together with certain other theories the author is careful to point out that all these hypotheses are still unproved and that the only way to obtain exact information on specific heats of gases and vapors lies through experimental determinations. (*Revue Générale des Sciences*, vol. 34, no. 14, July 30, 1923, pp. 425–435, *hpA*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

The American Society of Mechanical Engineers

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Coöperation of A.S.M.E. in Industrial Mobilization

FOR the first time in its history the United States of America by formal act of Congress has authorized the preparation of adequate plans for mobilizing industry for war emergency, and further has definitely designated a specific individual, the Assistant Secretary of War, as the person responsible for the provision of war essentials and the development of a suitable industrial organization to function during a war period. The National Defense Act, as amended June 4, 1920, which embodies these provisions, is proof that the United States learned its lesson from the recent war. No country, however rich in brains and money, can solve the war problems of design and procurement quickly and economically under conditions of war stress. The "highly complex matérial" demanded by a war machine and the correspondingly "highly organized industrial effort" are problems that require the coöperation of the entire people. All this is definitely pointed out and emphasized by General Williams in his article in this issue on mobilizing industry for ordnance production.

The heaviest responsibility for coöperation in industrial preparedness rests on the manufacturers and engineers who are daily solving production and distribution problems. To these men we especially commend the appeal of the Secretary of War for careful consideration of the preparedness plans.

In publishing this article by General Williams, which has the commendation of the Secretary of War and the approval of the Assistant Secretary, The American Society of Mechanical Engineers is proceeding in its consistent policy of wholehearted coöperation with the Government by enlisting the services and interest of its members in public problems. The Ordnance Division and the Secretary of the Society have intimate contact with the War Department, and as plans develop to the point where specific tasks can be assigned, individual members of the Society will be called upon to assist. As President Harrington points out in his letter on page 628 of this issue, the "plan of avoiding the belligerent attitude and the economic waste of men and means involved in a standing army, while keeping fit to meet effectively any emergency, is sound and in full accord with American ideals."

Calvin W. Rice.[1]

[1] Secretary, The American Society of Mechanical Engineers.

Engineering Education Hampered by New York Licensing Law

THE licensing law of the State of New York which recently went into effect has brought about a peculiar situation which discriminates against students of engineering. The state awards five scholarships in each county which entitle the holders to one hundred dollars a year for four years while in attendance at a college approved by the state. These scholarships are awarded on the basis of merit. The law stipulates, however, that while the person entitled to the scholarship is not restricted in the choice of the college or in the course of study, the scholarships shall not pay for instruction in theology or in any profession, admission to the practice of which requires a license from the state. On August 1 the New York State law requiring engineers to have a license in order to practice engineering went into effect, hence students electing engineering courses are now unable to receive the benefit of the state award.

Unlike the other professions where graduate courses are generally implied, the prospective engineer necessarily begins his engineering studies in his undergraduate course, the strictly professional training being usually obtained in practice rather than in graduate schools. The result of the present law is an unjust discrimination against engineering education, and already hardships have been imposed upon students who have chosen engineering as a life work.

The engineering societies have a definite responsibility to change this situation, and to do so they will require the assistance of every individual in the profession.

W. H. Kenerson.[1]

Measurement

PROGRESSIVE changes in any science may be illuminatingly studied by following the development of the instruments and apparatus for measurement used in its field, inasmuch as progress in discovery is the direct result of improvement of measuring devices. The march of improvement in machine production from the early days of the nineteenth century, when each mechanic made his own foot rule, is a direct reflection of the improvement in linear and angular measurement. Today an accuracy of one in forty thousand is ordinary practice.

Management entered the realm of science when engineers began to segregate the factors of production and measured them. Time study, methods of wage payment, machine idleness, etc. have been segregated and are now measured. Professor Roe in his paper in this issue applies the methods of engineering measurement to the measurable factors of management by comparison with practical standards, and suggests a general method of comparison between its performances at different periods. Very wisely Professor Roe recognizes that many factors evade the possibility of measurement and judgment must prevail.

Preliminary plans for Management Week reflect the wide interest that is being taken in the measurement of management, and it is safe to prophesy that the discussion of the papers to be presented at the various meetings will do much to define the methods which should be employed for that purpose. These may serve at the beginning—as the first foot rules—until better instruments are devised.

An interesting and exceedingly valuable method for measuring one of the economic factors has been contributed by the Materials Handling Division in its Formula for Computing Economics of Labor-Saving Equipment which appeared in the September issue of Mechanical Engineering. This formula merits the attention of every industrial engineer and executive, for it covers in simple form all of the elements which must be taken into consideration in installing new equipment of any kind. Its application is not limited to material-handling equipment. The principle involved applies equally well to all production equipment, and in deciding upon whether a new machine tool should be installed, the formula may be used with very slight modification.

Engineers are particularly fitted to devise such measuring instruments for solving the problems of industry, and it is safe to say that their profession is on the verge of great contribution in its field.

[1] Professor of Mechanical Engineering, Brown University, Chairman A.S.M.E. Committee on Relations with Colleges.

A.S.M.E. Annual Meeting, December 3 to 6

THE strong technical program to be carried out at the coming Annual Meeting of the A.S.M.E. and the 1923 Power Exposition make a combined attraction that should insure a large attendance in New York City at both events during the first week of December. The forty-fourth Annual Meeting of the American Society of Mechanical Engineers will open on Monday, December 3. The meeting will last for four days and will be made up of eighteen sessions covering the various branches of mechanical engineering. This year the Power Exposition will parallel the meeting. However, the meeting sessions of interest to engineers in power work will be scheduled for the morning hours and as the Power Exposition does not open until one o'clock each day, no conflict is anticipated. Last year over forty-seven thousand engineers visited the Exposition. This December the floor space devoted to exhibits will be approximately fifty per cent larger, and their variety is to be greatly augmented. Members of the A.S.M.E. will be admitted to the Exposition upon showing their Society badges or membership cards.

As a topic of general engineering interest the Annual Meeting will emphasize the fundamentals upon which hydroelectric development must be based. One evening session will be devoted to this subject, and the American Society of Civil Engineers and the American Institute of Electrical Engineers are coöperating in the preparation of the program. Mr. John R. Freeman, Past-President of both the A.S.C.E. and the A.S.M.E., will open the meeting and his address will be discussed by representatives of the three engineering societies.

There will also be a joint session with the American Society of Refrigerating Engineers.

The Professional Divisions on Aeronautics, Forest Products, Fuels, Gas Power, Machine Shop Practice, Management, Materials Handling, Ordnance, Railroads, and Textiles will be represented on the program. The Power Test Codes Committee will hold a public hearing and the Research Committee on Fluid Meters will present a portion of its report for public discussion. The Research Committee on Steam Tables will hold a public meeting to discuss progress in the research, and the Committee on Education and Training for the Industries will hold a conference for the discussion of problems of industrial education.

The November 7 issue of the *A.S.M.E. News* will contain the complete program with the list of papers and authors. The Committee on Meetings and Program has decided to confine preliminary publicity about the meeting to the *A.S.M.E. News* Special circulars about the meeting will not be sent out and members are counseled, therefore, to consult the *A.S.M.E. News* for meeting announcements.

All in Six Weeks

IN THE last six weeks several notable events have occurred illustrating the rapid progress of engineering in this country of ours.

On September 7 a novel type of prime mover was set up commercially for the first time in the central station of the Hartford, Conn., Power and Light Co., which promises to prove of great interest to the engineering world. This is a mercury boiler and turbine developed by W. L. R. Emmett, Mem. A.S.M.E., of the General Electric Co. The principle of the invention is fairly well known. Advantage is taken of the fact that mercury boils at a very much higher temperature than water, and the plant is really a combination of two parallel systems—mercury and steam. The mercury vapor generated in the boiler is first used to drive a turbine, after which it is condensed in a water-cooled condenser and then returned to the boiler. In condensing, the mercury converts the cooling water into steam, which is then superheated and delivered to a conventional steam turbine. The experimental unit was completed in 1913 and it took ten years of work (including the serious interruption caused by war conditions) to solve the numerous problems of design, in particular those dealing with the prevention of mercury leaks. From all indications it would appear that the plant is very efficient as regards the conversion of the latent heat of the fuel into power. The new installation, representing a unit of several thousand kilowatts, may be expected to contribute materially toward the determination of the commercial features of the combination plant.

The seaplane races in England in which American machines carried off the first and second prizes, the International Air Meet at St. Louis, Mo., and the preliminary elimination trials in this country for the two events, have thrown a remarkable amount of light on the progress of aeronautics in general, and American progress in particular, in the last few years. Speeds in excess of 230 miles per hour have been quickly attained and at St. Louis were maintained over a distance of something like 150 miles. To understand the great progress represented in such a trial it should be borne in mind that the attainment of such truly terrific speeds represents not merely an engine problem but an all-round engineering achievement. The progress of a heavy machine through the air at a speed of one-quarter that of sound would impose on the entire structure enormous stresses even if it took place in still air, and the air is never still for a big body like an airplane moving through it at these speeds.

It would be no exaggeration to say that the difficulties encountered by a designer of airplanes increase approximately as the cube, and possibly the fourth power, of the speed. The significance of this will be realized all the better by noting that in none of the recent speed trials has there been an accident involving loss of life or serious injury to the fliers.

The increase in our knowledge of aeronautics and methods of construction of airplanes has found expression in another direction, namely, the successful completion at McCook Field, by the Air Service, War Department, of the giant Barling bomber. Here again the difficulties of design rapidly increased with the size, and while huge machines like the Sikowski, Caproni, and—in this country—Martin bombers have been built before, each one failed, while the Barling appears to be quite maneuverable and has already successfully covered the distance from Dayton, Ohio, to St. Louis, Mo.

The bombing tests carried out off the coast of Virginia have probably not settled the question as to the extent to which an airplane endangers modern battleships. The fact remains, however, that both the *Virginia* and the *New Jersey*, two battleships which were scrapped under the Washington agreement as to limitation of naval armaments, have been sunk by aerial bombs. This has been taken by the Navy as showing the importance of aerial protection for battleships, probably parallel to the protection by destroyers from submarines and mines, the necessity for which has been recognized for a long time. The same tests, though with aerial maneuvers previously executed, have shown that in the first place a new and powerful weapon of naval combat has been recently created in this country, and second, that even with the existing facilities any point on the Atlantic seacoast can be given aircraft protection within seven hours from the appearance of danger, and that aircraft can operate over considerable distances out at sea from emergency hangars on shore.

The commissioning of the *Colorado* represents a notable achievement of American marine engineering. It is a superdreadnaught of 32,600 tons displacement with two 18,000-hp. turbo-electric generators delivering power to four 8000-hp. electric propeller motors. This arrangement of steam-turbine electric-propeller drive has been developed in this country and more widely adopted in the American Navy than anywhere else. Its armament of eight 16-in. guns in two forward and after turrets is the largest permitted under the Washington conference, and as long as the limitations of this conference stand the *Colorado* may be said to represent the last word in battleship construction.

We think of ourselves as young industrially, and yet the country has reached an age where anniversaries of its achievements in that sphere are being celebrated with increasing frequency. The latest of these, the semi-centennial of the typewriter, was recently held in Ilion, N. Y. While several attempts were made before to produce a machine of this character, Christopher Latham Sholes was the first to succeed in making one sufficiently perfected for commercial use. The earliest model built by Sholes with the assistance of Glidden and Soulé was made out of wood. It did write, but in a rather crude way, and the letters were not evenly aligned. Sholes was advised to take this invention to the firm

of E. Remington and Son in Ilion, who at that time were already engaged in the manufacture of small arms and were very unusually experienced in precise manufacturing for those days. They were also one of the few American concerns of half a century ago who maintained a research department. The connection between Sholes and the Remingtons proved a happy one and undoubtedly contributed largely to the success of the machine.

It is comparatively little known (though the story has been published before) that Thomas A. Edison helped in the development of the Sholes typewriter. Some time in the '70's Edison was asked to assist in the development of an automatic telegraph apparatus invented in England and working on the now familiar principle of a perforated tape. In his efforts to produce a device that would print a message directly in letter form instead of in dots and dashes, Edison ran across the Sholes typewriter, which was then available only in the form of a wooden model. An interesting fact illustrating the dependence of inventions on conditions other than mechanical is that while Edison succeeded in perfecting the automatic printing telegraph nearly fifty years ago, it did not come into extended use in this country until quite recently. During the same period, however, the Sholes typewriter has been built by the million and has become a fundamental element in the business life of the country.

It may also be of interest to note the difference between the spread of the typewriter in America and in the British Isles, both English-speaking countries. While its use is universal in all kinds of business and Government institutions on this side of the water, typewritten documents were considered rather informal until quite recently in England. For example, in lawyers' offices mechanical writing did not dislodge the quill until the stress of the war broke down the old tradition.

Cause of Explosion at Bureau of Standards

THE ignition of a mixture of gasoline vapor and air was found to have been the cause of the explosion in the altitude chamber of the Dynamometer Laboratory of the Bureau of Standards at 2 p.m., September 20, 1923. The explosion caused the death of four men and injured six others.

The altitude chamber, in which the explosion occurred, is a small concrete room, the walls and doors of which are designed to stand an external working pressure of about 1500 lb. per sq. ft. and is used for testing motors under the conditions of low air pressure and temperature encountered at high altitudes. At the time of the explosion it was being used for a "winter" test on an automobile engine in connection with a series of tests now being conducted at the Bureau to compare the efficiency of utilization by automobile engines of gasoline of various degrees of volatility. The chamber was closed up tight with no one in it, and the temperature had been lowered to about zero at the time the explosion occurred.

A special Board of Inquiry, headed by Lyman J. Briggs, physicist at the Bureau, made a detailed examination and presented a report in which the following explanation of the disaster was given:

> The explosion was caused by the ignition of a mixture of gasoline vapor and air in the altitude chamber. The Board believes that the presence of the gasoline vapor in the chamber was due either to a leak in the feed line leading to the carburetor of the engine or to a leak from the carburetor due to the sticking of the float mechanism. This conclusion is supported by a remark made by one of the members of the testing staff an instant before the explosion, to the effect that the gasoline readings which he was taking indicated the presence of a leak.
>
> The condition of the set-up following the fire is such that it is not possible to establish which one of the above causes occasioned the leak. Since it is known that only three gallons of gasoline had been drawn for the test, that the engine had been running from about 11 a.m. to 12 noon with the chamber open, that the chamber was closed at about 12:30 for the purpose of running at a lower temperature and that the engine had been operated from about 1 to 2 p.m. with the chamber closed, it is believed that not more than a quart of gasoline could have escaped into the chamber. This amount, however, if vaporized, would have been sufficient to account for the energy of the explosion.
>
> The probable source of the ignition was a backfire through the carburetor. Support to this conclusion is given by the statement of one of the survivors that he heard the engine backfire immediately before the explosion.
>
> The explosion threw out of the chamber a closed apparatus containing about ten gallons of heavy lubricating oil and about five gallons of toluol, breaking the pipe connections and thus releasing part of the contents, which furnished additional fuel for the fire which followed.

The report commended the courage and efficiency with which those on the scene handled the situation and especially the action of C. M. Smith, engineer in charge of the ammonia plant. Mr. Smith, a man of about sixty, was blown out of the door of the building and on to a pile of scrap lumber. His leg was badly bruised, his head cut, and his glasses smashed. Injured though he was, he returned to the wrecked chamber and shut off two ammonia valves, and then went to the refrigerating plant in the basement and operated it to pump the ammonia out of the coils in the wrecked chamber. This action may have prevented further loss of life and the destruction of the entire building by fire.

Results of First International Foundrymen's Congress

OUTSTANDING among the results of the First International Congress of Foundrymen, held in Paris, September 12–15, 1923, and participated in by representatives of eight countries, are (1) the unanimous passage of a resolution recommending international research on testing the quality of iron entering into castings and testing the quality of the castings themselves; (2) the unanimous passage of a resolution recommending the purchase and sale of pig iron on the basis of its analysis; and (3) the formation of a European Malleable Association to deal with technical but not commercial questions.

About thirty American foundrymen attended the congress, which was organized by the Association Technique de Fonderie de France with the coöperation of the Association Technique de Liège (Belgium), the Institute of British Foundrymen, the American Foundrymen's Association, the Association de Fonderie Tchéco-Slovaque, and independent foundrymen of Spain, Italy, and other European countries. Papers prepared by members of these organizations for the congress were presented in both French and English for the most part, and aroused considerable discussion.

An exhibition of foundry machinery and equipment which opened on September 2 continued through the Congress and was visited by a large number of foundrymen. The exhibits included a number of machines built under American patents, shown by French companies, and a few displays of American, British, Belgian, and Italian firms, but the majority were French designs. An educational exhibit of patterns and castings, and molding machines and sand-treating machinery in actual operation, attracted particular attention.

The American delegation spent about two weeks in England before the opening of the Congress as guests of the Institute of British Foundrymen, the National Ironfounding Employers' Federation, and the British Iron and Steel Institute. They were entertained in London, Sheffield, Manchester, and Birmingham, visiting a number of English iron, steel, and non-ferrous foundries, as well as historical and scenic points of interest. At the Hecla works of the Hadfields, Ltd., near Sheffield, where Sir Robert Hadfield was host, and at the adjoining plant of Edgar Allen & Co., the foundrymen were given an opportunity to study British steel-foundry practice, and at Manchester they were conducted through the plant of the Metropolitan-Vickers Electrical Co., Ltd., where over 7000 men are engaged in the manufacture of Westinghouse products.

In Sheffield and in Manchester, before branches of the Institute of British Foundrymen, Dr. Richard Moldenke presented a paper on American Foundry Practice, taking up present tendencies and methods of operation, and led a discussion of cast-iron testing and pig-iron specifications which were later the subject of resolutions at the Paris congress. Before leaving England the party visited the Shipping, Engineering, and Machinery Exhibit at Olympia, London.

In addition to the action taken in regard to testing cast iron, pig-iron specifications, and a European malleable association, the congress was of great importance and value to the foundrymen of all the countries, through their representatives, who became acquainted with European foundry practice both through the papers and discussion at the congress and through the inspection of plants in England and France. A spirit of international coöperation for the advancement of founding methods was evident on all occasions, and great enthusiasm shown for the proposed second conference to be held in this country in 1926.

Detroit Engineers Discuss Municipal Problems

[Mr. Burton's paper on The Fundamentals of City Zoning, which appears in abstract below, was the winner in the Civic Welfare Contest held last spring under the direction of the Associated Technical Societies of Detroit.

One of the objects of this Michigan organization is to increase the interest of the technical man in his city, to inform him about the problems of its growth, and in the solution of these problems to enlist his capacity for decision on a fact basis. The presentation and discussion of municipal problems before meetings of engineers is but the first step toward the ultimate goal of a close alliance between engineers and public affairs. The situation is strongly stated by H. M. Waite, a civil engineer of standing, who, from a four-year period as city manager of Dayton, Ohio, knows whereof he speaks.

"We need the man of practical affairs in public life," says Mr. Waite. "We have too many laws. We cannot enforce what we have. What we need now is readjustment. We need the engineering mind to readjust conditions created through the laws passed by lawyers. We need the practical mind to take the present developed country and apply common sense to its readjustment to conditions as they exist today. Engineers cannot do this by discussing papers. They must take a position in public life.

"The engineer cannot solve this problem alone but he can help. My belief is, that to get the engineer in a helpful mental attitude it is necessary to preach two things to him: First, that the engineer is not a superior being only to be courted from behind his maze of technical education. The engineer must be educated to give, in a practical way, the knowledge which he has. Second, the engineer must be taught that government is a business, and the only way it is possible to get business methods into government is to have the engineer with business judgment enter public life."—Editor.]

The Fundamentals of City Zoning

By FRANK BURTON[1]

AMONG the civic problems which have confronted the citizens of growing communities in recent years none perhaps has been the subject of more heated debate, and certainly none has been discussed with less understanding of the fundamental principles involved, than that of zoning. The congregation of many people in small areas, the erection of high buildings, the unforeseen developments in transportation and industry, together with a rapidly rising standard of living conditions and a greater development of the sense of civic responsibilities, have fundamentally altered our ideas of property rights and mutual responsibilities.

It may be that a farmer or miner possessed of land whose value is derived entirely from the products of the soil or the rocks, should be left to an unrestricted use and enjoyment of his land. The value of the city dweller's land, however, is due purely to its relative location with regard to some center of population. Its value is a function of its distance from some important point where persons are accustomed to congregate, and can be measured in terms of the number of people who pass on the adjacent street each day. It is these people who confer upon the property its value. It is because they work and earn money with which they must purchase the necessities and luxuries of life, that this property has acquired a certain value. Is it not absurd to say, then, that those who have so bountifully bestowed a great value where no value would exist without them, may not withhold some of that value if in so doing a great good can be accomplished for all?

Zoning as we now understand it is simply the laying of restrictions on the use of city property by ordinance, such restrictions differing in different zones or areas and having for their object a more equitable distribution of rights and obligations. They may cover the use of land or buildings, the height of buildings, or their size with relation to the lot upon which they are erected.

The good citizen of today, proud of his home, jealous of its surroundings, objects strenuously to the encroachment of industrial and commercial buildings, and in this he receives the sympathy of the great majority of his fellow-citizens. Therefore it requires no argument to convince people that zoning should prohibit commercial and industrial institutions from being established in purely residential neighborhoods.

Students of zoning believe, however, that we should go much further than simply to regulate the conditions surrounding dwelling houses. They point out that the proximity of factories, warehouses, etc., is detrimental to commercial institutions such as retail stores and offices. Certainly it is true that in New York City valuable commercial districts have been greatly damaged and depreciated by the intrusion of sweat shops, the crowds of workers going to and from such establishments having driven away the shoppers that formerly frequented these districts.

However, one of the most harassing problems confronting our City Plan Commission today would be disposed of if that body would abandon its attempt to separate commercial and industrial uses.

Another feature of zoning is that of separating the most objectional industrial uses from the ordinary or non-objectionable uses. Thus iron foundries, slaughter houses, heavy chemical plants, and similar institutions would be kept separate from other factories which do not produce objectionable smoke, odors, or dust. This certainly would be very advantageous to many industries and there is little objection to it as a principle, but in practice the drawing of regulations is very difficult and requires great engineering knowledge. The enforcement of such restrictions will require the greatest study and care in order that justice may be done and that no unreasonable obstacle shall be placed in the path of our city's industrial development.

Beside the restrictions as to use of business property, students of zoning favor limitations as to height and the percentage of lot to be occupied by such buildings. It is generally conceded that in the most congested parts of the city it is unwise to try to legislate regarding the percentage of a lot that may be occupied, but over the question of height there has been a bitter debate.

The opponents to the limitation of height plead high value of real estate and high taxes, but high buildings set close together in congested areas are not good investments and are undesirable from a civic standpoint. It is safe to say that no sound solution of city development can be found until stringent restrictions are imposed on the height of buildings in our congested districts.

No attempt has been made herein to outline the exact terms or form which the zoning ordinance should take, but we might properly review some of the advantages which the advocates of zoning believe will result from a properly prepared ordinance.

Such an ordinance will insure to the property owner a fair and reasonable enjoyment of his investment, by warning him in advance of what may be expected in the way of future development in a given district, and by excluding undesirable buildings which will encroach upon and depreciate the value of his building.

Further, investments will be stabilized and the great economic loss resulting from the premature destruction of buildings will be avoided. It is a common sight to see fine large houses being torn down to make room for mercantile buildings. As a community we know that in the end we must pay for all the good buildings destroyed before the end of their economic life. Commercial enterprises must shoulder the loss and charge it up to capital invested, when in reality nothing is invested.

There are other advantages of zoning not so obvious as those pertaining to buildings. For example, pavements suitable in width and construction for residential districts are unsuitable for industrial districts. Sewer systems, electric-power lines, water mains, street-car lines and other public utilities should be designed with some definite program as to the future development of the district, otherwise they may have to be torn up and replaced at an early date, with a consequent loss to the city at large. In fact, scarcely a branch of city planning can be executed with anything approaching efficiency without some knowledge of what the future will produce. True, zoning alone will not enable us to predict future developments, but it is the best, and in fact the only, step in that direction which we are able to make at this time.

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Engineering and Industrial Standardization

Standards for Cold-Finished Shafting

THE Sectional Committee on the Standardization of Shafting has recently completed a letter ballot on the first of its three reports. This report covers standards for (1) Diameters for Cold-Finished Transmission Shafting, (2) Diameters for Cold-Finished Machinery Shafting, (3) Tolerances on Diameters of Cold-Finished Transmission and Machinery Shafting, and (4) Stock Lengths for Cold-Finished Shafting.

The American Society of Mechanical Engineers is Sponsor for this Sectional Committee, so this report is now before this body for final approval and adoption, after which it will be transmitted to the American Engineering Standards Committee for approval as a "Tentative American Standard." The proposed standards are as follows:

Standard Diameters for Cold-Finished Transmission Shafting shall be:
15/16; 1-3/16; 1-7/16; 1-11/16; 1-15/16; 2-3/16; 2-7/16; 2-15/16; 3-7/16; 3-15/16; 4-7/16; 4-15/16; 5-7/16; and 5-15/16 in.

Standard Diameters for Cold-Finished Machinery Shafting shall be:
Size intervals extending to $2^1/_2$ in., by sixteenth inches; from $2^1/_2$ in., to 4 in., inclusive, by eighth inches; from 4 in. to 6 in. by quarter inches.

Standard Tolerances for Diameters of Cold-Finished Transmission and Machinery Shafting shall be:

Diameter	Tolerance
From 0.000 to 1.000 in. (inclusive)	(minus) 0.002 in.
Over 1.000 to 2.000 in. (inclusive)	(minus) 0.003 in.
Over 2.000 to 4.000 in. (inclusive)	(minus) 0.004 in.
Over 4.000 to 6.000 in. (inclusive)	(minus) 0.005 in.

Standard Stock Lengths for Cold-Finished Shafting shall be:
16, 20, and 24 ft.

Czechoslovakia's National Standardization Association the 17th to be Organized

AN INTERESTING account of the organization, functions, and methods of work of the Czechoslovak Standardizing Association was recently printed in *Strojnicky Obzor*, the particulars being obtained from a lecture delivered by Mr. B. Rosenbaum at a technical school in Prague as part of a course on Standardization and Organization. Following are extracts from the summarizing paragraphs of the speaker.

The Czechoslovak Standardizing Association was organized by the metallurgical and metal-working industries. Its program first calls for the standardization of the elements of machines, rules governing the metal-working industry, and gradually the widening of its scope to include other branches of industry. It plans not only to standardize, but also to segregate into types the manufactured articles and parts, and to support every activity tending toward standardization. The Association has started logically by standardizing iron and steel products.

This, of course, involves the standardization of rolled and drawn iron stock and shapes. To accomplish this they invited the coöperation of the smelters and manufacturers of iron and steel not only for metal-working industry, but for industry in general. The manufacture and use of iron concerns all branches of industry, the industrial bureaus of the government, the entire industrial life. It is logical and necessary, therefore, to invite all these interested groups when attempting to establish standards in this field.

The government from the very beginning saw the importance of the Czechoslovak Standardizing Association and supported its organization. The first item of receipts of the C.S.A. was a gift of 10,000 crowns by the Department of Labor. The government delegated representatives of six departments to serve on the Board of Directors. In this way a concord between the plans of the government and of the industries is assured.

All of the largest metal-working establishments are now members of the C.S.A. They not only supply numerically the largest financial support, but they help the standardization activity much more effectively in that they offer for its use all their own factory standardizing experiences and results, and detail from their force specialists to aid in the standardization work of the Association.

The Association employs a sufficiently large permanent staff of experts on which it depends primarily for the effectiveness of the standards work. Standards are not originated by the staff. Their substance and contents are created by the technical representatives of the manufacturers, the consumers, the government, and the scientific institutions. The C.S.A. office staff does, however, prepare the material for the committees, gathering it from both home sources and from foreign countries. It works up the material that has been discussed at meetings and refers this worked-up material to the committees again, and so on, until finally the standard is approved by the committee. The office then arranges it in convenient form for examination by the Board of Directors, upon whose approval it is published so that the general public may have an opportunity to examine and criticize it while in tentative form.

It is apparent that the course of a standard from the beginning to its final acceptance is very long and demands a great amount of work on the part of the headquarters office, both administrative and technical. It is necessary to call the meetings of the various committees and to communicate with the committee members by mail. In many instances it is necessary to keep two or more committees informed concerning the progress of each other's work, so that duplication will be avoided. The more working committees there are, the faster will be the progress of standardization.

In closing, the author says:

Words cannot adequately express the scope of the standardization which should be undertaken. Perhaps the making of a more accurate estimate of the advantages of standardization, when carried on in a national way, for a number of objects whose standardization is very necessary, will show these advantages to be so enormous that the seemingly large expenses connected with the work involved will be infinitesimal in comparison. The standardization activities of the C. S. A. have so far been most generously supported by machine manufacturers who have the most advanced factory standardization. They support the general standardization program though they perhaps need it the least. Apparently their familiarity with purposeful standardization makes them better able to appreciate the importance of general standardization.

Faults and Virtues of Standardization

A RECENT ISSUE of the New York *Times* contained a brief article from the pen of Dr. Charles W. Eliot, President Emeritus of Harvard University, entitled Blight of Standardization. Dr. Eliot introduced his subject with the following paragraph:

A new blight is afflicting education and industries in the United States, particularly the educational part of industries. Its name is standardization, and there is a very general movement to give it application in a great variety of American activities. The blight seems to have started in the industrial domain. To save time, and therefore money, and to increase the productiveness of a given plant, the movements of the individual operative were carefully studied with a view to reduce the number of his movements and changes of posture, and to increase the automatic and repetitive quality of his work. The object was larger production at lower cost, and this object was gained; but the inevitable result was the destruction of the interest of the workman in his work. For the life-long interest of the handworker in the varied products of his skill was substituted the intolerable dullness of tending machinery on a standardized "stop-watch" program.

The article then went on to state that the ideal in education is to develop the utmost possible variety of individual attainment and of group attainment; just as the true goal of democracy is the free development of the utmost variety of capacity in the individual citizen. Dr. Eliot then observed that

It will be for the happiness of the American people to look carefully into the effects of standardization in both the national education and the national industries. It has already gone too far. Although some pecuniary economies can be effected by standardizing processes in both schools and factories, their physical and moral effects are unquestionably bad. As soon as any process in State or Church proves to be injurious to the physical or mental quality of the population a genuine democracy should set to work to modify or suppress it.

Mr. Albert W. Whitney, Chairman of the American Engineering Standards Committee, took exception to the title of Dr. Eliot's article and to some of his statements, and accordingly prepared a reply which was published in the September 2 issue of the New York *Times*. He said in part:

President Eliot's letter describes some of the evil effects of an unwise use of standardization, but in doing so he condemns standardization in general.

Standardization cannot be disposed of so summarily. Like any other powerful instrument, it has its dangers; the problem, however, is not how to get rid of it but how to use it. Standardization can be used safely just as high-tension electricity can be used safely.

As a matter of fact, standardization, which is essentially only the selection and preservation of the best among a mass of the inferior, is at the bottom both of natural evolution and of civilization. Evolution has produced species—standardized types that have proved their fitness to survive. Civilization has produced institutions, and these have been recorded in laws and customs. Both of these processes are essentially standardization, and the extent to which evolution and civilization have gone is measured by such standards.

Mr. Whitney then pointed out that our lives are not only con-

trolled but made possible by standardization. Standardized bodies make possible medicine and surgery. Without some degree of standardization in our mental processes modern education would be impossible. Progress consists primarily in the ability to consign certain standardized actions to the domain of routine, thus setting the mind and the emotions free for fresh adventure and conquest. In the evolution of the mind and body parts of the body have even been set aside as standardization centers, the reflex nervous centers, where standardized actions, namely, habits, are taken care of so that the brain need not be bothered with them. Then speaking principally for engineering and industrial standardization, Mr. Whitney summed up his argument in the two following paragraphs:

> I dislike to state anything so obvious, and yet it appears to be necessary, for there is a very general tendency today to confuse the dangers and excesses of standardization with the process itself. As a matter of fact, an overwhelming proportion of the standardization work that is being done today has the highest social value; it is at the very root of the task of making a better and safer and more interesting and generally more worth-while world—safer steel rails and bridges and buildings, better traffic regulation, better health, better opportunities for recreation and education, less poverty, more leisure, more art, more freedom in religion.
>
> The principal dangers in standardization are, first, a too early standardization before the trial stage has been completed; second, a too rigid standardization that does not allow for necessary and ever-present change; third, a too peremptory standardization that is not satisfied to rest the case on innate excellence; fourth, a too ambitious standardization that pushes into fields where it does not belong, particularly the field of essentially emotional and spiritual values. That the problem of getting the good effects of standardization without its bad effects is a serious one no one who is a thoughtful student of standardization would deny; but it's simply one more problem in a world of difficult problems, that's all.

Dr. Eliot replied to Chairman Whitney in a personal letter from which we are permitted to quote the following:

> I heartily believe in the great usefulness of the work of the American Engineering Standards Committee, and sympathize in everything you say about what standardization in the proper sense means and does not mean, attempts and does not attempt. When I wrote about the blight of standardization, I had no idea of objecting to such standardization as your Committee labors for and vigorously promotes.

Westinghouse War Memorial Scholarships

FOUR scholarships each carrying an annual payment of five hundred dollars per year are awarded annually by the Westinghouse Electric and Manufacturing Company to employees and sons of employees on the basis of competitive examination, as a Westinghouse War Memorial. Under the plan of awarding four scholarships yearly, four men would be graduated yearly, the total number of scholarships in force at one time being sixteen.

The effort of the company in selecting men for these awards has been to find young men of a many-sided nature. Intelligence, physical qualities, aptitude for engineering work, and ability to shoulder responsibility and to guide their own affairs have been the general points on which the candidates are compared.

The feature of the plan that provides the officials of the company with a means of keeping up the continuity of the personal contact with the men as their college course progresses, is bringing them to the works for the periods of the summer vacations. In this way the men are given the opportunity of securing practical experience as well as of adding to their financial resources. By the time of graduation, the year's work in the shops required of all engineering graduates entering the company's employ has been practically completed.

After graduation, with the exception of one who preferred construction work, all the men have entered the employ of the Westinghouse Company, finding their way into field work in the Service Department, Commercial Engineering, Research Department, Design Departments, etc.

The schools at which Westinghouse War Memorial men have been trained or are now in training include Carnegie Institute of Technology, University of Pittsburgh, University of Cincinnati, Leland Stanford University, University of Pennsylvania, Pennsylvania State College, Cornell University, University of North Carolina, California Institute of Technology, Haverford College, and Ohio State University.

Measurement of Management

(*Continued from page 636*)

Farquhar, Henry H. Measuring the Performance of the Production Department. *Harvard Business Review*, April, 1923, p. 331.

Knoeppel, C. E. Measuring Waste in Industry. *Bulletin of the Taylor Society*, April, 1922.

Williams, J. H. A Technique for the Chief Executive: A Definite Responsibility—A Definite Procedure—A Definite Measure of Results. *Bulletin of the Taylor Society*, April, 1922.

Robert Morris Associates. Financial Statements: An explanation in brief of a system for their analysis from the standpoint of the credit grantor and of the business executive. The Robert Morris Associates, 1922.

Roe, J. W. The Measurement of Management. Paper before the Society of Industrial Engineers, Detroit, 1922.

Dunn, William E. Measuring Executive Ability. *Industrial Management*, May 1, 1922, p. 292.

Benedict, H. G. Performance Ratings for Salaried Executives. *Bulletin of the Taylor Society*, August, 1922.

Clark, Wallace. The Gantt Chart. Ronald Press Co., N. Y., 1922.

Dunn, William E. The Measure of Management. *Bulletin of the Society of Industrial Engineers*, March and April, 1923.

Schlink, F. J. The Measurement of Management. *Management and Administration*, August, 1923, p. 173.

Bliss, James H. Financial and Operating Ratios in Management. Ronald Press Co., N. Y., 1923.

Chemical Warfare Service

(*Continued from page 646*)

containing primer, propelling charge and projectile proper, with its equipment of primer and bursting charge, is dropped in at the open end, and so rapid is the operation of the machine that one shell can be actually fired out of it before the preceding one has reached its target.

One of the great disadvantages of the existing Stokes mortar is its lack of portability. At the same time it is obvious how useful such a machine could be if made portable for rear-guard action, wiping out machine-gun nests, etc. Its usefulness from a military point of view would be enormously increased if it could be adapted for firing Chemical Warfare type shells, for example, shells filled with mustard gas or white phosphorus.

Fig. 5 shows one type of cart that has been devised for the purpose, but several others are under development. In general, it is expected that the means of transportation will consist of a caisson carrying approximately 15 rounds of 4-in. Stokes mortar shell complete with fuses and propelling charges. These caissons will be arranged for either animal or manual traction. To the caisson will be limbered another two-wheeled cart arranged to carry a Stokes mortar complete with baseplate or tools and accessories.

The Chemical Warfare Service is organized as an autonomous part of the War Department. It is working in very close coöperation with the Air Service which realizes the great possibilities that poison gases and smoke screens open to it. It has a special liaison officer attached to it from the Ordnance Department, in addition to which the close proximity of the Aberdeen Proving Grounds to the Edgewood Arsenal insures ease of communication between the two services. The U. S. Navy is also showing a lively interest in the work of the Chemical Warfare Service, frankly realizing the consequences that might be the result of an attack by poison gas on an unprotected ship and the advantages of smoke screens and similar devices.

While the most important features of the work of the Chemical Warfare Service for obvious reasons cannot, and indeed should not, be described, it is believed that enough has been said to indicate the general character of this work and to show that as far as possible everything is being done to insure proper protection for the American soldier against the new forms of attack, and that our Army has the ability to hold its own in this field whenever it may be called upon to do so.

Cost Control For Foundries. By Frank Everitt and Johnson Heywood. McGraw-Hill Book Co., New York, 1923. Cloth, 6 × 9 in., 226 pp., illus., $3.

A detailed description of the theory, practice and routine of cost accounting for foundries, presented in a way that can be easily understood by foundrymen with no claim to accounting knowledge. The method described is planned to be simple and inexpensive, yet accurate. It is fully set forth, and a complete set of the necessary forms is given. The method is applicable to foundries of varying kinds and sizes.

Die Dampfturbinen, Vol. 2. By Const. Zietemann. Walter de Gruyter & Co., Berlin and Leipzig, 1923. Boards, 4 × 6 in., 141 pp., illus., $0.25.

This, the second volume of this little handbook, discusses in its first section the thermal calculations the selection of the size or number of stages and the determination of the blade velocity. Two worked-out examples are given, showing how the methods are used. Sections two and three deal with the design and construction of the moving and the stationary parts of turbines. The treatment is extremely concise, but thoroughly practical.

Davison's Textile "Blue Book," 1923–24. Davison's Publishing Co., New York, 1923. Cloth, 7 × 9 in., 1729 pp., maps, $7.50.

The "Blue Book" is a comprehensive directory of American firms engaged in the textile industries as manufacturers, dyers, bleachers, brokers, commission merchants, or dealers in raw or waste materials. The information on mills includes the location, capacity, number of employees, officials, capitalization, etc. The directory is classified by products and by location, and a name index is provided. A directory of supply dealers is included.

Dictionary of Applied Physics, Vol. 5: Aeronautics; Metallurgy; General Index. By Sir Richard Glazebrook. Macmillan & Co., London, 1923. Cloth, 6 × 9 in., 592 pp., illus., diagrams, tables, 63s.

The concluding volume of this valuable work of reference is divided in two parts, treating of aeronautics and metallurgy, respectively. Part one contains long articles on Full-Scale Aerodynamical Research, by R. M. K. Wood; Experimental Tests of Strength of Aeroplane Structures, by W. D. Douglas; Theory of Aeroplane Structures, by W. L. Cowley; Doping and Fabrics, by Guy Barr; Performance and Stability of Aircraft, by Leonard Barstow; Airscrews and Helicopters, by Arthur Fage; Experiments on Airships, by J. R. Pannell and R. Jones; Diffusion through Membranes, by Guy Barr; Engines, by G. H. Norman; Model Experiments, by E. F. Relf and H. B. Irving; and Hydrodynamical Theory, by Hermann Glauert.

Among the longer articles in part two are: Typical Alloy Systems, the Equilibrium Diagram and the Relationship of Structure and Physical Constants, by J. L. Haughton; Special Alloys and Aluminium Alloys, by Walter Rosenhain; Aluminium, by Donald Finlayson; Electric Furnaces, by F. A. J. FitzGerald; Laboratory Furnaces, and Refractories, by E. A. Coad-Pryor; Invar and Elinvar, by C. E. Guillaume; Iron-Carbon Alloys, and Defects and Failures of Metals, by D. Hanson; Relations of Strain and Structure, Thermal Study and Thermal and Mechanical Treatment, by Walter Rosenhain; Aggregation and Flow of Solids, by W. D. Haigh; and Special Steels, by W. H. Hatfield. An index to the volume and a general index to the whole work are included.

Electrical Vibration Instruments. By A. E. Kennelly. Macmillan Co., New York, 1923. (Engineering Science Series.) Cloth, 6 × 9 in., 450 pp., illus., diagrams, tables, $6.50.

Dr. Kennelly's book presents, from an electrical engineering viewpoint, the characteristics of telephone receivers, and of other vibrational instruments, as reciprocating electric motors. It is based on researches carried on at the Massachusetts Institute of Technology and at Harvard University during the past fourteen years. The book is intended as a textbook for students of telephone engineering, and also as a reference book on the receiver for telephone engineers.

Elementary Thermodynamics of Automobile Engines. By Erwin H. Hamilton. McGraw-Hill Book Co., New York, 1923. Cloth, 6 × 9 in., 287 pp., illus., tables, $3.

This book presents the fundamental principles of the thermodynamics of internal-combustion engines, as used in automobiles, with sufficient detail to illustrate them properly. It is intended as a textbook for college students and as an advanced text for trade schools.

Elements of Radio Communication. By Ellery W. Stone. Second edition. D. Van Nostrand Co., New York, 1923. Cloth, 5 × 8 in., 318 pp., illus., diagrams, $2.50.

Prepared originally for radio students in the Communication Service of the Navy, this book has proved suitable for use in other schools and for self instruction. The subject is presented physically rather than mathematically, in a manner requiring but little previous knowledge on the part of the reader. This edition has been thoroughly revised and enlarged by the addition of recent developments.

Estimating Building Costs. By Charles F. Dingman. McGraw-Hill Book Co., New York and London, 1923. Fabrikoid, 4 × 7 in., 240 pp., tables, $2.50.

In preparing this volume, Mr. Dingman has had in mind the needs of the young man in the building business who wishes to become an estimator. Particular attention is given to the exposition of principles and to methods, so that the reader will be trained to analyze construction jobs into their components, to apply his cost data, adjusted to the conditions, to the necessary operations, and thus to calculate the cost of doing the work.

Factory Management Wastes and How to Prevent Them. By James F. Whiteford. D. Van Nostrand Co., New York, 1920. Cloth, 6 × 9 in., 220 pp., charts, $4.

Of the work of the average factory, about one-fifth deals with the processing and treatment of materials, and this in usually efficiently done in a well-organized way. The remaining four-fifths of the work, dealing with the common things, done day after day by routine, is seldom well organized. It is here that the greatest wastes are to be found. It is the purpose of this book to discuss these wastes, their causes, detection and remedies. Removal of them will, the author believes, remove some of the prevalent difficulties between employer and employed, manager and managed. The subjects discussed include works organization and management, production control, machinery, performance records, overtime, cost finding, wages and profit sharing.

Forest Resources of the World. By Raphael Zon and William N. Sparhawk. First edition. McGraw-Hill Book Co., New York and London, 1923. Cloth, 6 × 9 in., 2 vols., maps, tables, $12.

An inventory of forest resources in all countries. In order to make it possible to compare different countries, an attempt has been made in every case to show the forest area, annual growth and annual cut, and to make deductions from these factors as to the forest resources of the different countries. The topics discussed for each land are: forest area; character and distribution of forest; character of ownership; annual growth; annual cut; exports and imports; domestic consumption; progress in forest conservation; and the probable future. A mass of useful information, hitherto widely scattered, is brought together and conveniently summarized. References to sources of information are included.

Die Linienführung der Eisenbahnen. By H. Wegele. Edition 2. Walter de Gruyter & Co., Berlin and Leipzig, 1923. Boards, 4 × 6 in., 110 pp., illus., diagrams, tables, $0.25.

A very brief summary of the principles of railroad location and construction, revised to meet present conditions. Discusses the problems of an economic and a technical nature that arise, the principles that govern transportation, and the governmental regulations for railroad construction and operation in Germany. A convenient reference book.

Patents Throughout the World. By William W. White and Wallace White. Trade Mark Law Publishing Co., New York, 1923. Cloth, 6 × 9 in., 244 pp., maps, tables, $7.50.

In this digest of the patent laws of the different countries, a uniform arrangement of the data under the same headings has been adopted for each country. Ready reference is further facilitated by a chapter of general information on foreign countries and by a series of tables which show at a glance the conditions under which patents may be obtained from the various governments. The book will be useful to inventors and patent attorneys.

Phase Rule and Its Applications. By Alexander Findlay. Fifth edition. Longmans, Green & Co., New York and London, 1923. Cloth, 6 × 9 in., 298 pp., illus., diagrams, tables, $3.50.

The object of the author is to give a non-mathematical exposition of the phase rule and its applications which will explain the principles underlying it and illustrate its use. The book is intended as an introduction to the subject for students of chemistry and also as a textbook for students of metallurgy and geology.

The advances in the subject which have occurred since the appearance of the fourth edition, in 1914, have necessitated the complete revision and rewriting of certain sections and the addition of much new matter.

Practical Heat. By Terrell Croft. McGraw-Hill Book Co., New York and London, 1923. Cloth, 6 × 8 in., 713 pp., illus., tables, $5.

Practical Heat is intended to present the subject of heat and its practical applications in a manner that may be followed by persons with limited mathematical attainments. The text begins with the consideration of the fundamental concepts of physics, force, pressure, work, energy, and power. Next follows a discussion of heat, its source and its relation to matter. This is followed by the measurement and transformations of heat, where the first and second laws of thermodynamics and the fundamental equation of heat transference are explained. The effects of heat, expansion, heat phenomena of gases, etc., are next considered.

Succeeding chapters discuss gas and vapor cycles, fuels, combustion, power plants, heating, refrigeration and measuring instruments, attention being directed to the demonstration of the way in which theoretical principles are applied in engineering practice.

Railroad Electrification and the Electric Locomotive. By Arthur J. Manson. Simmons-Boardman Publishing Co., New York, 1923. Cloth, 6 × 9 in., 332 pp., illus., diagrams, tables, $4.

A book written to give railway officials and operating men a knowledge of the design, construction and operation of electric locomotives and of their application to different kinds of railroad service. The book opens with a statement of theoretical principles, which is followed by descriptions of the various motors and other elements of the electric locomotive, illustrated by examples from practice. Examples of the solution of problems encountered in electrification are given. An appendix contains a brief history of the electrification of American steam railroads and a number of useful tables covering electrification projects throughout the world.

Railroads, Rates, Service, Management. By Homer B. Vanderblue and Kenneth F. Burgess. Macmillan Co., New York, 1923. Cloth, 6 × 9 in., 488 pp., $4.50.

The authors of this book, professor of business economics at Harvard University and general attorney of the C. B. & Q. R. R. Co., respectively, have written it to give information concerning the elaborate system of governmental machinery by which railroad regulation is accomplished in the United States. The book is intended for those with an interest in the methods of regulation, for students of railroad practice, and for railroad officers. It is neither a law book nor a text on economics, but is rather a volume presenting the observations that have resulted from experience in teaching the subject and in active practice before courts.

Robert Fulton and the Submarine. By Wm. B. Parsons. Columbia University Press, New York, 1922. Cloth 7 × 10 in., 154 pp., illus. portraits, $4.

An interesting record of Fulton's submarine boats, of his experiments in France and England, and of his unsuccessful attempts to interest the governments of those countries in his invention. Much of the material is here published for the first time and is taken from recently discovered descriptions written by Fulton himself.

Scientific Management and the Engineering Situation. By Sir William Ashley. Humphrey-Milford, Oxford University Press, London, 1922. (Barnett House Papers, no. 7.) Paper, 6 × 9 in., 28 pp., $0.35.

This pamphlet contains the Sidney Ball Memorial Lecture delivered before the University of Oxford, 28 October, 1922, by the Vice-Principal of the University of Birmingham, Sir William Ashley, who devotes himself to criticism of scientific management, particularly as applied to engineering and the metal trades. His examination is analytical and his attention is particularly directed toward the method of remuneration of labor. He finds much to criticise unfavorably from the viewpoint of the student of economics, in present theories of management, and indicates his objections briefly in an interesting way.

Special Steels. By Thomas H. Burnham. Isaac Pitman & Sons, London, 1923. (Pitman's technical primers.) Cloth, 4 × 6 in., 194 pp. illus., diagrams, tables, $1.70.

The author of this book endeavors to meet the need for some work from which the student or user of special steels can obtain a concise technical survey of the nature and scope of this branch of metallurgy.

After a general introduction and description of the constitution and manufacture of special steels, the important steels are described, special consideration being given to their working, heat treatment and uses. Appendices give bibliographic references for those desirous of further information.

Strome und Spannungen in Starkstromnetzen als Grundlage Elektrischer Leitungsberechnungen By Josef Herzog, and Clarence Feldmann. Walter de Gruyter & Co., Berlin and Leipzig, 1923. Boards, 4 × 6 in., 110 pp., diagrams, tables, $0.25.

A concise presentation of the theoretical considerations in the design of distributing systems for electric power. The little volume is intended as a vade mecum for the engineer, not as a textbook for the student. The methods for calculating distributing networks are set forth explicitly, in spite of the briefness of the text.

Théorie des Surfaces Portantes; La Théorie de Prandtl. By Maurice Roy. Gauthier-Villars et Cie., Paris, 1922. Paper, 5 × 8 in., 131 pp., diagrams, 12 fr.

An attempt to present in a simple manner the basis of the theory of supporting surfaces elaborated in Germany by L. Prandtl in the aerodynamic laboratory at Göttingen, and to present the results obtained up to the present time. Part one sets forth the fundamental idea of the theory and includes a study of two interesting problems raised by Joukowski's theory. The second part describes the applications of a simplified form of the theory, presented by Professor Prandtl before the Göttingen Scientific Society, in the design of wing surfaces and propellers.

Vorlesungen uber Ingenieur-Wissenschaften; Part 2, Eisenbruckenbau, Vol. 3. By Georg Christoph Mehrtens. Wilhelm Engelmann, Leipzig, 1923. Paper, 7 × 10 in., 445 pp., illus., diagrams, tables, $5.10.

This, the concluding volume of Professor Mehrtens' lectures on steel bridges, is divided into four sections. Section one treats of girder systems and their calculation. Section two discusses the structural details of truss bridges of various kinds, while section three is upon the details of suspension bridges. The final section describes the fabrication and erection of bridges, and includes accounts of the erection of the Manhattan, Queensboro, and Hell Gate bridges. The volume is very fully illustrated.

Die Walzwerke, Einrichtung und Betrieb. By A. Holverscheid. Walter de Gruyter & Co., Berlin and Leipzig, 1923. Boards, 4 × 6 in., 144 pp., illus., diagrams, $0.25.

This little work describes modern rolling-mill machinery and practice. Mills for structural iron, sheets, wire and pipe are described, as well as a number of mills for special purposes. An appendix on heating furnaces is included. The treatment is condensed, but covers the essentials.

THE ENGINEERING INDEX

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Exigencies of publication make it necessary to put the main body of The Engineering Index (p. 117-EI of the advertising section) into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.

AIRPLANE ENGINES

Wright. A New Powerplant. Aviation, vol. 15, no. 14, Oct. 1, 1923, p. 409, 2 figs. Details of Wright model T3 aviation engine.

AIRPLANES

Navy-Wright Racing. Navy-Wright Racing Plane Is Built Around 700-hp. Engine. Automotive Industries, vol. 49, no. 14, Oct. 4, 1923, pp. 687–689, 8 figs. Plywood construction used in fuselage and wings; latter contain radiator units which are arranged for ready removal if damaged; 12-cylinder power plant said to develop 132 lb. per sq. in. b.m.e.p. and weigh 1.77 lb. per hp.

AUTOMOBILES

Brakes. Hydraulic Four-Wheel Brakes for Automotive Vehicles, Malcolm Loughead. Soc. Automotive Engrs.—Jl., vol. 13, no. 4, Oct. 1923, pp. 313–316 and (discussion) 316–321, 3 figs. Author answers citations in disfavor of 4-wheel brakes and compares external with internal brakes in favor of external type; details of hydraulic 4-wheel brake system and design requirements; advantages of hydraulic compared with mechanical type of 4-wheel brake.

Chandler. Chandler Adopts New Type of Gearset for 1924 Model. Automotive Industries, vol. 49, no. 13, Sept. 27, 1923, pp. 645–646, 3 figs. Unit is manufactured under Campbell patents; does away with necessity for sliding gears into mesh laterally by use of system of keys; full-pressure oil-feed system installed.

Packard. The Packard Single-Eight, J. G. Vincent and W. R. Griswold. Soc. Automotive Engrs.—Jl., vol. 13, no. 4, Oct. 1923, pp. 257–275, 27 figs. Fundamental characteristics; components of engine performance; crankshaft design; gas distribution; fuelizer operation; cylinder and valve gear; arrangement of accessories; transmission design; fundamental requirements of brakes and steering; wheel forces and rolling resistance; mechanics of brake construction.

BUILDING MATERIALS

Heat Conductivity. The Conductivity of Building Materials. Engineering, vol. 116, no. 3011, Sept. 14, 1923, pp. 338–339. Account of experiments dealing with true conductivity, measured under steady flow of heat, based on report published by Building Research Board.

COST ACCOUNTING

Expense and Burden Distribution. The Taylor Method of Expense and Burden Distribution, Paul M. Atkins. Indus. Management (N. Y.), vol. 66, no. 4, Oct. 1923, pp. 217–223, 4 figs. Describes one of earliest attempts to work out sound cost accounting system.

DROP FORGING

Dies. The Preparation of Drop Forging Dies, Leslie Aitchison. Forging—Stamping—Heat Treating, vol. 9, no. 9, Sept. 1923, pp. 368–375, 16 figs. Discusses factors to be considered in design of drop-forging dies; various stresses set up in die blocks should be carefully analyzed.

ELECTRIC FURNACES

Iron Foundry. Producing Synthetic Gray Iron in the Electric Furnace, Edwin L. Willson. Elec. World, vol. 82, no. 9, Sept. 1, 1923, pp. 431–433, 1 fig. Experiments by Hartford Elec. Light Co. indicate commercial possibilities for use of excess off-peak hydroelectric energy; iron-foundry industry offers new field for electric-furnace application.

FREIGHT HANDLING

Combined Electric Railway and Truck Transport. Electric Railway and Truck Transport Combined by Use of Container Cars, D. M. McDonald. Automotive Industries, vol. 49, no. 14, Oct. 4, 1923, pp. 678–680, 6 figs. Detroit United Lines installs comprehensive system which will result in marked shipping economies; door-to-door service is made possible; shippers may use their own or street-car company's motor vehicles.

GEARS

Grinding Teeth of. Gear Tooth Grinding, Franklin D. Jones. Machy. (N. Y.), vol. 30, no. 2, Oct. 1923, pp. 85–95, 20 figs. Principles of different gear-tooth grinding processes; types of gear-tooth grinders, and their application.

HEATING, STEAM

Centralized Control. Centralized Control of Steam-Heating System Based on Outside Temperature. Power, vol. 58, no. 14, Oct. 2, 1923, pp. 528–530, 4 figs. Describes Donnelly distributed heat system which controls entire supply from one central point in accordance with outside temperature and heats at nearly constant temperature; steam supplied is then distributed mechanically to all radiators.

HYDRAULIC TURBINES

Governors. Recording Hydraulic-Turbine Governor Operation with an Oscillograph, A. F. Bang. Power, vol. 58, no. 12, Sept. 18, 1923, pp. 446–447, 3 figs. How turbine speed, gate movement, and penstock pressure were recorded simultaneously with oscillograph.

Results of Seventy-Three Tests Made of Hydraulic-Turbine Governors. Power, vol. 58, no. 15, Oct. 9, 1923, pp. 560–564, 9 figs. Tests conducted to determine how parallel operation of hydroelectric and steam plants 40 miles apart could be improved; investigation of governors, effects of kinetic energy in machine's revolving parts, and power-system reactance.

INDUSTRIAL MANAGEMENT

Engineers and Production Manager. Engineers and Production Managers, Charles S. Dahlquist. Soc. Automotive Engrs.—Jl., vol. 13, no. 4, Oct. 1923, pp. 310–312. Defines duties of engineer and production manager and describes attitude of mind that each usually has toward other, that is too often unfavorable.

INDUSTRIAL TRUCKS

Special-Design. Making the Equipment Fit the Job, Matthew W. Potts. Indus. Management (N. Y.), vol. 66, no. 4, Oct. 1923, pp. 231–239, 13 figs. Special-design trucks that have solved special handling problems.

INTERNAL-COMBUSTION ENGINES

Single-Valve. Single-Valve Internal-Combustion Engine Design and Operation, R. Abell. Soc. Automotive Engrs.—Jl., vol. 13, no. 4, Oct. 1923, pp. 301–309, 10 figs. Specification is made of 13 essential factors that author believes are necessary for attaining better engine performance; describes how improved results have been obtained by use of single-valve mechanism on engine having unusually high compression ratio and using ordinary gasoline as fuel; details and test data of latest type of engine built with single-valve mechanism.

LOCOMOTIVES

Mountain Type. Canadian National Mountain Type Locomotive. Ry. & Locomotive Eng., vol. 36, no. 9, Sept. 1923, pp. 274–276, 1 fig. Representing latest development in Canadian design of high-speed passenger engine, and are largest passenger engines in Canada; overall length of engine and tender is 90 ft.

MACHINE DESIGN

Maintenance Factor in. The Maintenance Factor in Machine Design, W. E. Irish. Indus. Management (N. Y.), vol. 66, no. 4, Oct. 1923, pp. 201–205, 2 figs. Shows how maintenance man, with his intimate knowledge of where and why breakdowns occur, is valuable consultant when new equipment is to be bought; gives example of hydraulic-pump installation to show what came from designer's board and how maintenance man made alterations.

MACHINE TOOLS

Typewriter Manufacture. Special Machines in a Typewriter Plant, Carl Gabrielson. Machy. (N. Y.), vol. 30, no. 2, Oct. 1923, pp. 128–132, 9 figs. Unusual mechanisms incorporated in design of special high-production machines.

OIL FUELS

Heating Value, Determination of. The Determination of the Calorific Value of Liquid Fuels, Nelson Harwood. Engineering, vol. 116, no. 3013, Sept. 28 1923, p. 396, 1 fig. Describes volume method which produces constant temperature range in calorimeter throughout each experiment.

PIPE, CAST-IRON

Centrifugally Cast. Casting Iron Pipe Centrifugally, E. C. Kreutzberg. Iron Trade Rev., vol. 73, no. 13, Sept. 27, 1923, pp. 871–875, 9 figs. Rotating chill molds are used to form bell-and-spigot-type cast-iron pipe; core required for bell end only; mixture of high silicon content is used; product is annealed.

PUMPS, CENTRIFUGAL

Diesel. Diesel Centrifugal Pumping Plant for the Metropolitan Water Board. Engineering, vol. 116, no. 3011, Sept. 14, 1923, pp. 332–333, 12 figs. partly on p. 336 and supp. plate. The plant consists of two pumping sets, which are together capable of delivering in 24 hours 9,000,000 gal. against head of 300 ft.

Experimental Design. Development of High Efficiency in Centrifugal Pumps, A. F. Scherzer. Eng. News-Rec., vol. 91, no. 14, Oct. 4, 1923, pp. 561–564, 7 figs. Describes recent program of experimental design carried out in hydraulic laboratory of University of Michigan.

PUNCHING MACHINES

Design. Design of Punching and Shearing Machines, A. Lewis Jenkins. Machy. (N. Y.), vol. 29, nos. 11 and 12, and vol. 30, nos. 1 and 2, July, Aug., Sept and Oct., 1923, pp. 841–848, 974–975, 34–38 and 113–118, 21 figs. July: Formulas for determining dimensions of various parts. Aug.: Formulas for use in proportioning camshaft and driving clutch. Sept.: Designing gear, pinion, countershaft, pulley, and flywheel. Oct.: Calculating and laying out frame sections.

RAILWAY MOTOR CARS

Gasoline. Powerful Gasoline Motor Driven Train Ry. Mech. Engr., vol. 97, no. 9, Sept. 1923, pp. 640–642, 7 figs. Sykes Co. demonstrates two-car train driven by 245-hp. engine and seating 74 passengers.

Local-Passenger Train. A Motor Car Train for Local Passenger Service on the Chicago Great Western Railway. Ry. & Locomotive Eng., vol. 36, no. 9, Sept. 1923, pp. 271–273, 5 figs. Train consists of motor and trail car, seating 30 and 44 passengers respectively; engine of motor car is Sterling 6-cylinder gasoline motor.

RAILWAY REPAIR SHOPS

Erecting-Shop Practice. Erecting Shop Practice on the Southern Pacific, H. C. Venter. Ry. Mech. Engr., vol. 97, no. 9, Sept. 1923, pp. 654–658, 13 figs. Efficient devices and methods for expediting erecting-shop work at Sacramento shops are described.

Locomotive Repair. Progressive Repair System for Locomotive Shops, Lawrence Richardson. Ry. Mech. Engr., vol. 97, no. 10, Oct 1923, pp. 741–718, 3 figs. Straight-line method used in modern industrial plants applied to classified repairs.

Locomotive Scheduling. Locomotive Scheduling at the Silvis Shops, L. C. Bowes, G. F. Sandstrom and H. K. Robinson. Ry. Mech. Engr., vol. 97, nos. 9 and 10, Sept. and Oct., 1923, pp. 643–645, 6 figs., and 699–700. Sept: Analysis of cost-accounting division. New schedule system to provide centralized control of production. Oct.: New schedule system designed to provide centralized control of production and accurate cost data. Performance.

SCREW MACHINES

Automatic. A Recently Developed Automatic Screw Machine. Am. Mach., vol. 59, no. 13, Sept. 27, 1923, pp. 469–470, 2 figs. Unusual design of slide tool; feed motion through worm gearing; cam-operated cross slides; four work spindles mounted in combination bearings.

SEAPLANES

Besson Quadriplane. The Besson Commercial Seaplane. Engineer, vol. 136, no. 3535, Sept. 28, 1923, pp. 346–347, 3 figs. Details of quadriplane which has been undergoing trials on Mediterranean coast.

SLOTTING MACHINES

Portable. Unusual Machine Work in Seattle, Fred H. Colvin. Am. Mach., vol. 59, no. 14, Oct. 4, 1923, pp. 497–499, 5 figs. Describes portable slotting machine built by Seattle Machine Works and some unusual work that had been done by it.

STEAM POWER PLANTS

Hydroelectric Additions to. Supplementing Steam Plants with Hydro. Elec. World, vol. 82, no. 14, Oct. 6, 1923, pp. 712–713, 1 fig. Factors determining availability of water-power additions; distribution of costs in hydroelectric plants; illustrative data method of analysis.

STEAM TURBINES

Aligning, Accurate. Accurate Methods of Aligning Steam Turbines—Using Sound to Increase Sensitiveness of Measurements, Edgar G. Barker, Sr. Power, vol. 58, no. 14, Oct. 2, 1923, pp. 526–527, 3 figs. Method for increasing accuracy of micrometer measurements.

STEEL

Repeated-Shock Tests. New Experiments with Repeated Shocks, Leon Guillet. Iron Age, vol. 112, No. 14, Oct. 4, 1923, pp. 890–891, 1 fig. Influence of cold drawing considerable, especially on ductility; ultimate strength and elastic limit raised; compression and elongation lowered. Paper presented before Franco-Belgian Assn. of Testing Methods (Translated from French.)

STEEL, HEAT TREATMENT OF

Annealing. Metallurgy and Heat-treatment of Steel Stampings, Ralph H. Sherry. Machy. (N. Y.), vol. 30, no. 2, Oct. 1923, pp. 105–108, 5 figs. Deals with cold working and annealing of low-carbon steel; grain growth and its restriction; requirements of annealing furnaces.

STEEL, HIGH-SPEED

Red-Hardness in. Cause of Red Hardness of High-Speed Steel, Edgar C. Bain and Zay Jefferies. Iron Age, vol. 112, no. 13, Sept. 27, 1923, pp. 805–810, 7 figs. New facts and theories; changes due to heat treatment; X-ray analysis; slip interference. Bibliography.

SUPERHEATED STEAM

Economies in Use of. Power Problems of Vital Interest to Executives, James T. Beard. Indus. Management (N. Y.), vol. 66, no. 4, Oct. 1923, pp. 211–216, 8 figs. Outstanding economies of superheated steam.

WAGES

Incentive Systems. Tendencies Toward the Incentive Method of Wage Payment, Ordway Tead. Indus. Management (N. Y.), vol. 66, no. 4, Oct. 1923, pp. 196–200. Discusses present trend and what it accomplishes.

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Mechanical Engineering

The Monthly Journal Published by

The American Society of Mechanical Engineers

Publication Office, 207 Church Street, Easton, Pa. Editorial and Advertising Departments at the Headquarters of the Society, 29 West Thirty-ninth Street, New York

Volume 45 | December, 1923 | Number 12

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ADVERTISING

Price 50 Cents a Copy, $4.00 a year: to Members and Affiliates, 40 cents a Copy, $3.00 a Year. Postage to Canada, 75 Cents Additional; to Foreign Countries $1.50 Additional. Changes of address should be sent to the Society Headquarters.

Entered as second-class matter at the Post Office at Easton, Pa., under the Act of March 3, 1879.
Acceptance for mailing at special rate of postage provided for in section 1103, Act of October 3, 1917, authorized on January 17, 1921.

N. R. Gibson

W. L. Churchill

E. L. Robinson

W. H. Tschappat

O. P. Hood

E. C. Peck

J. M. Lessells

Contributors to this Issue

Col. William H. Tschappat, Commanding Officer at the Aberdeen Proving Ground, contributes a paper to this issue on New Instruments for Physical Measurements which gives the results of recent research work conducted by the Ordnance Department at Aberdeen. Colonel Tschappat is an authority on ballistics. Two years after his graduation from the U. S. Military Academy he was transferred from his work in the Artillery to the Ordnance Department and his services here have been principally in connection with explosives and ballistics. He served for five years (1912–1917) as Professor of Ordnance and Gunnery at the U. S. Military Academy previous to his work at the Aberdeen Proving Ground.

Colonel Tschappat's textbook on Ordnance and Gunnery is published by John Wiley and Sons. He is the author of the article on Ballistics which appears in the latest edition of the Encyclopedia Britannica.

* * * * *

Norman R. Gibson was born in Guelph, Ontario, in 1880. Since his graduation from the University of Toronto his work has been devoted chiefly to problems of water-power development. He has had valuable experience in these problems on both sides of the river at Niagara Falls, and at present holds the position of hydraulic engineer for the Niagara Falls Power Company. He offers in this issue a paper on the Gibson Method and Apparatus for Measuring Flow of Water in Closed Conduits.

Mr. Gibson is a member of the American Society of Civil Engineers and of the Engineering Institute of Canada.

* * * * *

Ernest L. Robinson is the author of the paper on The Margins of Possible Improvement in the Central-Station Steam Plant. Since his release from the army he has been associated with the General Electric Company at Schenectady, devoting his activities to the structural improvement of the steam turbine and its more efficient application.

Mr. Robinson is a graduate of St. Lawrence University in the class of 1911. Three years later he was graduated from the Harvard Graduate School of Applied Design with a master's degree in civil engineering. His early experience was in structural engineering both steel and reinforced concrete, and also in water-power engineering. During the war he served in France as a first lieutenant with the 302d Engineers, and subsequently as captain and adjutant of the Second Engineer Training Regiment.

* * * * *

O. P. Hood, whose Factors in the Spontaneous Combustion of Coal appears in this issue, is chief mechanical engineer of the U. S. Bureau of Mines, and is in charge of the Bureau's fuel investigations. He was born in Lowell, Mass., in 1865 and holds degrees of B.S., M.S., and M.E. from Rose Polytechnic Institute. After leaving college Mr. Hood had some experience in the drawing and designing of small machinery, but after a few years he turned to teaching as a profession. From 1886 to 1898 he was in the engineering department of the Kansas State Agricultural College, and from 1898 to 1911 he was Professor of Mechanical and Electrical Engineering at the Michigan College of Mines, being engaged in general mechanical engineering practice as well. Since 1911 Mr. Hood has held his present position with the Bureau of Mines where his experience has fitted him to speak with authority on the fundamentals of coal storage with minimum danger of spontaneous combustion.

* * * * *

William L. Churchill sees a need for thousands of engineers in a field hitherto practically untouched by them which he discusses in his paper on The Mechanical Engineer in the Management of Woodworking Industries. Mr. Churchill is an established consulting engineer in industrial efficiency in New York City. He was born in Montpelier, Vermont, in 1871 and has devoted his life largely to developing the efficiency of the various organizations with which he has been connected.

While with the Pneumatic Service Company in Chicago, Mr. Churchill designed, developed, and constructed a new type of automatic cable-operated cash-carrier system for department stores. Later he became general superintendent for the Schreiber & Conchar Manufacturing Company at Dubuque, Iowa, and then superintendent of rates for the Yale & Towne Manufacturing Company. In 1908 he went with Stephen T. Williams and Staff of New York City, leaving them in 1912 to become works manager for the McKinnon Dash Company at St. Catherine, Ont. In 1914 Mr. Churchill entered the consulting field as an efficiency engineer, specializing on the diagnosis of causes for industrial inefficiency and prescribing and applying remedies. He has been a frequent contributor to the technical press.

* * * * *

J. M. Lessells, who presents some Notes on the Fatigue of Metals, was born in Dunfermline, Scotland, in 1888. Following a five-year apprentice course in mechanical-engineering work, he became a Carnegie scholar, attending Heriot-Watt College, Edinburgh, and the University of Glasgow, receiving his B.Sc. in Engineering from the latter in 1914. He was inspector of engines and aircraft material for the British War Department from 1914–1916, later becoming connected with the Rolls Royce Company in Derby, England. In 1920 Mr. Lessells came to this country where he is now in charge of research on problems in mechanics for the Westinghouse Electric and Manufacturing Company in East Pittsburgh. He is a member of the Institution of Mechanical Engineers and of the Automobile Engineers of London.

* * * * *

E. C. Peck, presents a paper on the Unilateral System of Tolerances. He was born in Akron, Ohio, in 1867. His early drafting-room and shop experience was gained with the Akron Iron Company, the Cleveland Twist Drill Company and the B. F. Goodrich Company. Then for five years he had charge of the twist-drill department of the Whitman & Barnes Company. Following this he held responsible positions with the T. & B. Tool Company, Danbury, Conn., the Morse Twist Drill & Machinery Company, New Bedford, Mass., and the Cards Tap & Die Company before returning to the Cleveland Twist Drill Company, where for many years he has held his present position as general superintendent.

Forest Conservation and Hydroelectric Development

are of tremendous importance to engineers and are to be stressed at the coming A.S.M.E. Annual Meeting, New York, December 3 to 6. An added attraction will be the National Exposition of Power and Mechanical Engineering to be held simultaneously. For details of the complete program see the *A.S.M.E. News* for November 7 and 22.

MECHANICAL ENGINEERING

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New Instruments for Physical Measurements

Instruments and Methods Developed in Connection with Recent Research Work by the Ordnance Department

By COL. W. H. TSCHAPPAT,[1] ABERDEEN, MD.

IT IS a well-known fact that the precision required in the construction of small arms, cannon and other ordnance matérial is, in many respects, greater than that required in the manufacture of commercial machinery. The tendency in ordnance construction has always been to hold to small clearances and correspondingly small tolerances. We can readily understand the necessity of accurate measurements in the construction of hand arms or small arms, and the use of small tolerances was found necessary during the long period of evolution of this type of weapon. At one period in the development of the art of gun making, this was about the only class of metal work which required accurate finishing. The gun lock was at one time about the most complicated piece of metal machinery. If we except the art of clock and watch making, which may be considered a craft in itself, it will appear that the art of gun making furnished the first incentive to accurate machine work.

Measurements of Distance

The Built-Up Gun. In the later development of the breech-loading cannon, the "built-up" cannon, and their complicated mounts devised to increase the rapidity of fire and the convenience of maneuvering, accurate measurements in various parts have been called for. As an example, the diameter of the bore of the 75-mm. gun across the lands is required to be 2.95 in. as a minimum with a plus tolerance of 0.004 in. The diameter of the "bourrelet" or forward bearing surface of the projectile fired from this gun is limited to a maximum of 2.938 in. with a minus tolerance of 0.005 in. As an accident, fatal to the gun if not to the crew, would be likely to occur if the minimum diameter of the bore or the maximum diameter of the bourrelet were exceeded, the necessity for accurate measurements of these parts can readily be realized.

This particular gun is of the type known as "built-up," which means that the jacket heated to a high temperature is assembled to the cold tube. Upon cooling the jacket contracts, exerting a pressure upon the tube which places the inside layers of its metal in a state of tangential compression. This construction adds to the strength of the gun by permitting the metal at the interior of the jacket, as well as that at the interior of the tube, to be brought into full play when the powder pressure is exerted in the gun. To accomplish this result, however, it is absolutely essential that the proper amount of shrinkage or difference between the interior diameter of the jacket and the exterior diameter of the tube when both are cold, be provided. If too much is allowed, the tendency is to crush the interior of the tube upon shrinkage and thus weaken or crack the interior of the bore. If too little is allowed, the full additional strength of the gun will not be developed.

In this gun the exterior diameter of the tube is 5.000 in. and the interior diameter of the jacket is 4.994 in. The shrinkage prescribed is 0.006 in. ± 0.001 in. In assembling, the jacket is first bored on the inside and the tube is then turned. If a single gun is made the dimensions of the tube are determined by the actual dimensions of the jacket in which it is to be assembled so as to give the required shrinkage. In quantity production the jackets to be assembled to tubes are selected by actual measurements so as to give the required shrinkage.

Pneumatic Recuperator. Another part of the gun, or rather its mount, in which extremely accurate work is required is the recuperator. Since the requirement in this mechanism is that a packed piston moving in a cylinder must not leak air or nitrogen under pressure, the necessity for extreme accuracy can be realized. Not only is the uniformity of the diameter of the cylinder of the recuperator of great importance, but the surface must be of such smoothness as not to wear out the packing of the piston nor permit the escape of gas. That the difficulties in doing this have been overcome is proved by the fact that recuperators have been known to have been in operation or storage for two or three years without appreciable loss of pressure. The attainment of this extreme accuracy of machine work was one of the problems of the war which was eventually solved by the American manufacturers who had contracts for this work.

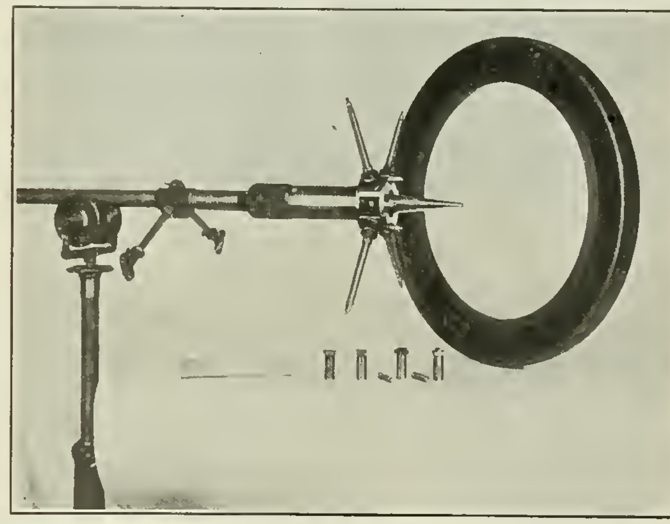

Fig. 1 Star Gage for Measuring Interior Diameters of Tubes and Hoops of Built-Up Guns

Star Gage. The interior diameters of guns, and of the component tubes and hoops of "built-up" guns, recuperators, etc., offer a special problem of measurement. On account of the great length of these parts compared with the interior diameter, it is not possible to obtain accurate measurements with gages of the ordinary type.

The instrument used for obtaining these measurements throughout the length is known as a star gage, and is shown in Fig. 1. Briefly, it consists of a head having four arms, as illustrated, of which two at opposite diameters contain radially moving measuring points operated by the steel cone which is moved in the direction of the rod by a screw thread. The other two arms are fixed and serve as guides to hold the instrument in a central position. Operation is by turning a handle at the end of the rod. Longitudinal scales on the rod serve to measure the distances from the end of the tube at which measurements are taken. The supports shown are necessary for long hoops to guarantee that the measurements will be taken at right angles to the bore.

It is the usual practice to take measurements with this instrument on two diameters at right angles to each other. In addi-

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Contributed by the Ordnance Division for presentation at the Annual Meeting, New York, December 3 to 6, 1923, of The American Society of Mechanical Engineers. All papers are subject to revision.

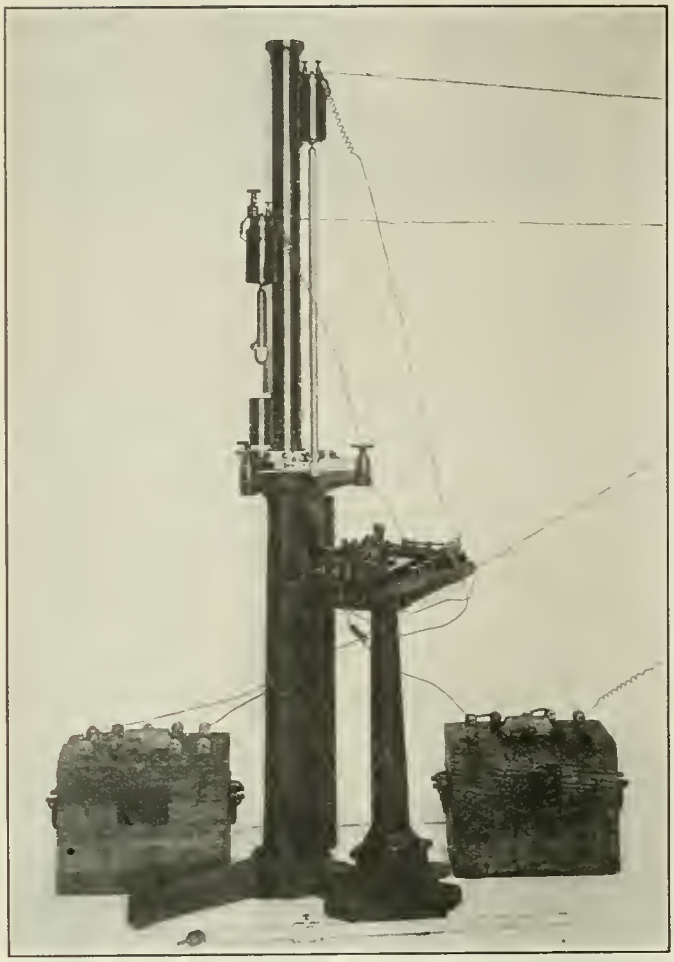

Fig. 2 The Boulengé Chronograph

tion to the interior measurements of hoops which are made before assembling, this instrument is used in measuring guns after firing to show what expansion has taken place, either due to the actual strain of the metal or the wearing out or erosion of the bore.

Several sizes of this instrument have been constructed, permitting the taking of these measurements upon the shoulder rifle having a diameter of the bore of 0.3 in., and on the 16-in. gun and all intermediate sizes.

Exterior measurements are made with calipers of a commercial type, and of course a great deal of ordnance construction is made with jigs and specially constructed gages. One very important use of ring gages is in the measurement of the diameters of projectiles.

Measurements of Time

The accurate measurements of distance which have been described are made during the manufacture of ordnance and, in so far as interior measurements of the bore are concerned, again during the "proof firing" or test to determine whether the gun will stand up. At this time measurements are also usually made to determine whether various parts of the mount, including the recuperator, are being distorted by the stresses put upon them by the firing. These measurements of distance are important as they are sure indications of whether or not the gun is equal to its work.

In the test of any experimental gun or mount it is, however, also desired to know at all rounds the velocity which is being given to the projectile. The velocity is obtained by measuring the time of passage of the projectile over a measured distance. The measurement of velocity therefore resolves itself into a measurement of time and a measurement of distance.

Boulengé Chronograph. The instrument almost exclusively used in the proving grounds of all countries until recent years for this measurement is the Boulengé chronograph. This instrument, illustrated in Fig. 2, is well known to many members of the Society and will not be described in detail. Its operation depends upon the breaking by the projectile of wires strung upon two screens placed at a known distance apart in front of the gun, thus interrupting the current in two circuits, each of which includes one of the screens and one of the magnets which support the rods of the instrument. The breaking of the first screen releases the long rod, and that of the second screen the short rod. The distance the long rod falls in the time of passage of the projectile between screens is recorded through the mechanism of a knife released by the impact of the short rod. The time is readily computed from the distance of fall.

This instrument has given long and efficient service at many proving grounds; however, malfunctioning and errors frequently result when long, sharp-pointed projectiles are used, for the reason that the screen wires either fail to break or break only after the point of the projectile has passed some distance through the screen. The result is either complete failure or an inaccurate result due to the change in distance between screens. For example, if the nominal distance between screens is 100 ft. and the projectile breaks the wires of the first screen when the point reaches them, and the wires of the second screen when the point has passed one foot beyond, the actual distance will be 101 ft. and the error in velocity computed from the nominal distance between screens will be 1 per cent. It was to overcome this defect of the Boulengé chronograph, which was accentuated by the tendency toward the use of sharp-pointed projectiles, that a study was started at the Aberdeen Proving Ground during the war which led to the development of the Aberdeen chronograph.

Aberdeen Chronograph. This instrument and the fall apparatus as constructed are shown in Fig. 3. The principle upon which it operates is shown diagrammatically in Fig. 4, which also shows on the right the apparatus used in calibrating it. Referring to Fig. 4, the instrument consists of a drum, a, 500 mm. in circumference, driven by a constant-speed motor b at the rate of 25 revolutions per second. A strip of record paper carried on the interior surface of the drum is held in position by centrifugal force. At the rotational speed the linear velocity of the strip is 12,500 mm. per sec. The operation of the instrument requires a source of direct current at 110 volts, preferably from an independent battery. This single source of power drives the motor and furnishes the current through the primaries of the induction coils as the projectile completes the circuits in the screens c, c. The latter consist of two sheets of tin (or tin or lead foil for small projectiles) separated by insulating material—cardboard or oiled paper. As the point of the projectile

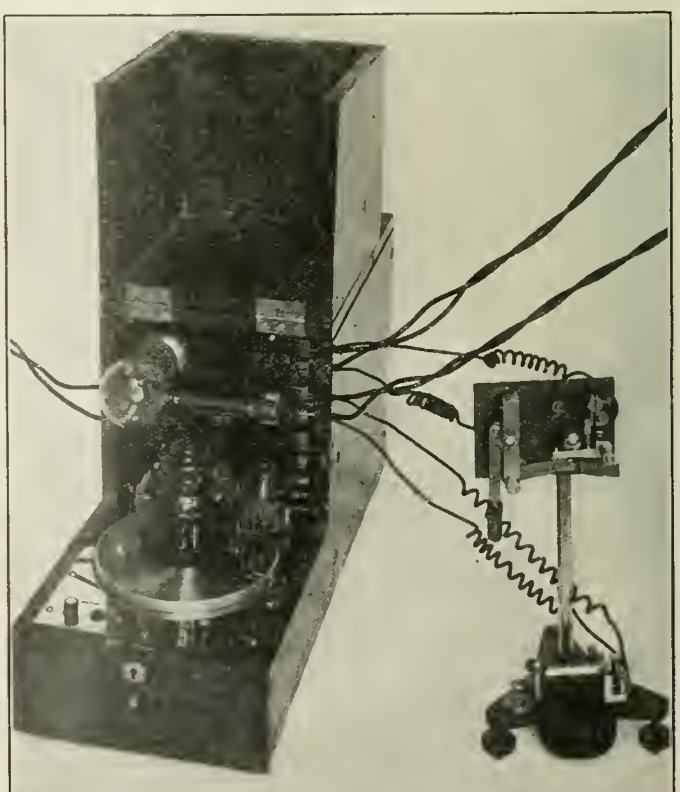

Fig. 3 The Aberdeen Chronograph

penetrates the screen it makes contact with the metal on opposite sides of the insulating material, thus completing the primary circuit in the induction coil and causing the secondary to produce a spark which pierces the record strip on the interior of the drum. There are three circuits and three spark coils provided in each instrument, so that it is possible to get a record with three screens. Since the drum is rotating with a uniform and known speed and the distance between screens is known, one may readily compute the average velocity between any two of the screens.

While tests have indicated that the governor of the motor actually does keep the speed very nearly constant over any short period of time, differences of temperature, state of lubrication, etc., may cause changes in speed. Since it is necessary not only that the speed be constant during the experiment but that it be known, the calibrating apparatus shown at the right of Figs. 3 and 4, known as the "fall apparatus," is used frequently when the chronograph is being operated. It may be seen that the two "make" points of this apparatus are each connected in parallel with one of the screen circuits. When the trigger mechanism of the fall apparatus is released, one of the primary circuits is closed, a spark is produced in the secondary, and the steel ball d begins to fall. When the ball reaches the base of the apparatus it closes the second primary, producing a spark in the corresponding spark point. The height of the apparatus is so designed that the time of fall of the ball corresponds to five revolutions of the drum. The records produced by the spark on the record strip should therefore be opposite each other. If they are otherwise, correction for the discrepancy can easily be made or the speed of the motor can be adjusted.

As a result of continuous use of this instrument at the Proving Ground over a period of five years, it has been demonstrated that its accuracy under the best conditions of use is fully equal to that of the Boulengé instrument under similar conditions. While inaccuracies result with the Boulengé instrument when sharp-pointed projectiles are being fired, this condition is favorable to the Aberdeen instrument. On the contrary, the Aberdeen instrument may give erratic results when blunt-nosed projectiles are being fired, due to poor contact at the screens. This can generally be overcome by fitting the noses of the projectiles with spikes. Better results are generally obtained with small projectiles than with large ones, probably on account of the more sudden "make" of the current

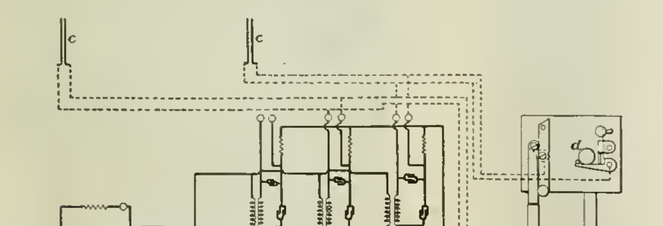

Fig. 4 Connections of the Aberdeen Chronograph

at the screens. Two hundred and twenty (220) volts in the screen circuits gives better results with large projectiles than 110 volts. Tests have shown that under favorable conditions both the Boulengé and Aberdeen instruments are capable of measuring short intervals of time with a mean error of 0.0001 sec. If the screens are 150 ft. apart and the projectile has a velocity of 3000 ft. per sec., it will require 0.05 sec. for the projectile to pass from the first screen to the second. If the instruments read 0.0501, the indicated velocity will be 150/0.0501 or 2994 ft. per sec., an error of 6 ft. per sec.

Measurement of Air Resistance on Projectiles of Various Forms

Ordnance engineers have long been aware of the marked increase in range that can be obtained with projectiles by constructing them with longer and sharper points. Before the late war this method of increasing the range was not taken full advantage of, as gun mounts then in existence seldom permitted the firing of guns at elevations corresponding to their maximum ranges. The nature of the fighting during the war was such as to give a marked advantage to the side having artillery of the longest range, and all expedients were therefore used to increase the range. It was found that other changes of form besides that of sharpening the point have the effect of reducing the air resistance and increasing the range. Important among these is beveling or "boat-tailing" the projectile at the rear end. The position of the rotating band is also found to have an important effect upon air resistance. Shortly

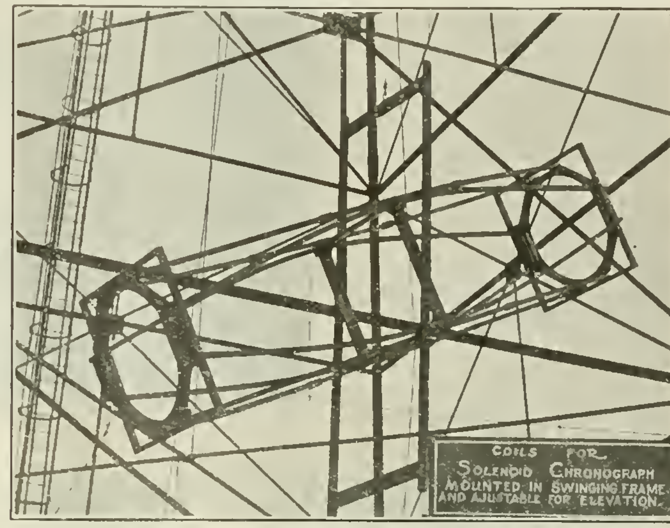

Fig. 5 Frame for Coils of the Solenoid Chronograph

after the war the Ordnance Department decided to make a thorough investigation of the effect of form of projectiles upon air resistance and consequent range.

The first scientific investigation of the air resistance opposed to a moving projectile was made by Bashford in England. Later, extensive tests were made by the Gavre Commission in France and Krupp in Germany. These later tests were made upon projectiles of the service type at the time, having a length of head about equal to the caliber, and a square base. The Ordnance Department decided to conduct experiments along two lines: (a) Suspend projectiles of selected forms in a moving air stream and measure the resistance by means of a mechanical balance; and (b) fire projectiles of selected forms and measure the velocities at several points down the range.

Method (a) has never been used before on projectiles, as the difficulty of obtaining an air stream even approximating the velocity of a modern projectile has been considered insurmountable. However, arrangements were made with the General Electric Company for the installation of a suitable orifice to connect with one of the large blowers manufactured by this company at Lynn, Mass. With this installation it has been found possible to obtain a velocity of 1200 ft. per sec. with a 12-in. orifice, and 1600 ft. per sec. with a 7-in. orifice.

Method (b) is the classical one for obtaining measurement of the air resistance opposed to projectiles. In principle it consists in determining the drop in velocity of the projectile at measured intervals of time and distance. Since the method depends upon the determination of differences in velocities amounting to a fraction of a per cent of the velocities themselves, one can readily see the necessity of having very precise measurements of the velocity. Although the Boulengé chronograph was formerly used for similar tests, it was considered highly desirable to use an instrument of greater precision if one could be obtained.

Solenoid Chronograph. As a result of this need, the Ordnance Department and the Bureau of Standards developed and put into operation an instrument known as the solenoid chronograph. An instrument involving the same principles had already been experimented with in England. The projectile, after being magnetized, is fired through coils of wire which may be mounted separately or at the ends of a cage as shown in Fig. 5. Separate mount-

ing is used for horizontal firing and cage mounting for firing at very high elevations.

The passage of the projectile through the coils generates a current which is led to an oscillograph and causes deflection of the mirror element of that instrument.

The chronograph camera, shown in Fig. 6, consists of a cylinder 5 ft. in circumference, driven by an electric motor at a speed of four or more revolutions per second, and so arranged that it can also be made to move axially. The cylinder is arranged to receive a photographic film 4 in. in width. It is completely enclosed by a lightproof housing which carries the shutter and a part of the optical system for focusing the light from the oscillograph mirror and from the timing apparatus.

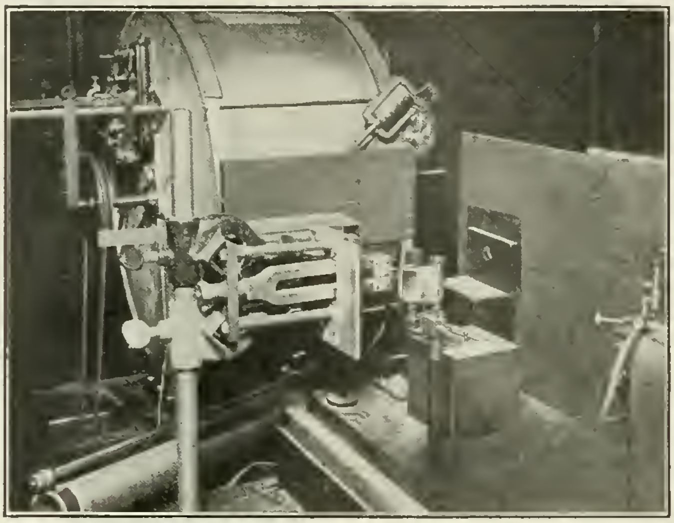

FIG. 6 THE SOLENOID CHRONOGRAPH CAMERA

The latter, shown in Fig. 6, consists of a tuning fork driven electrically in such a manner that the vibrating arms do not make physical contact at any point. Thin metal plates attached to the ends of each of the arms are provided with narrow slits which pass each other as the fork vibrates. The optical system is so arranged that light can reach the film only when the slits are superposed. The source of light is a carbon arc. To use the camera the film is placed in position and the light, the tuning fork, and the electric motor are started. The switch for firing the gun is then closed, thus opening the shutter and operating the translating mechanism of the drum.

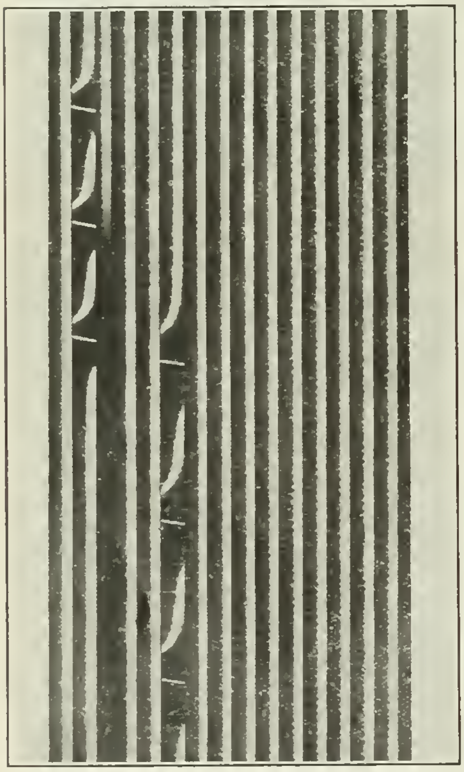

FIG. 7 RECORD MADE BY SOLENOID CHRONOGRAPH CAMERA

(Jogs in the oscillograph lines indicate passage of projectile through the coils.)

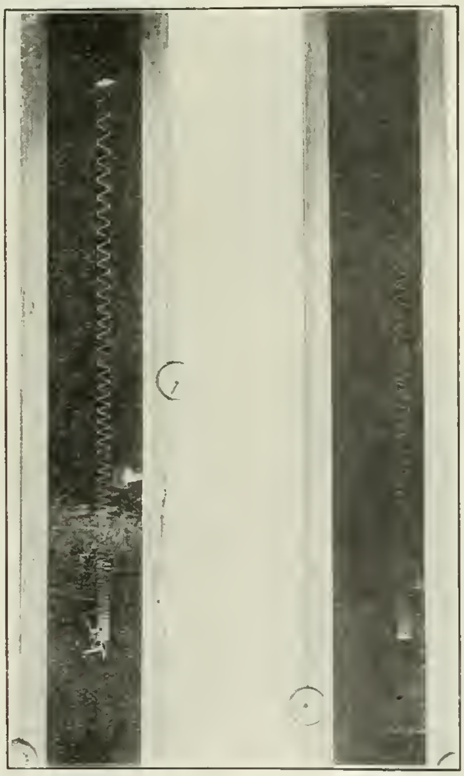

FIG. 8 RECORD OF RECOIL OF GUN MADE BY THE SEBERT VELOCIMETER

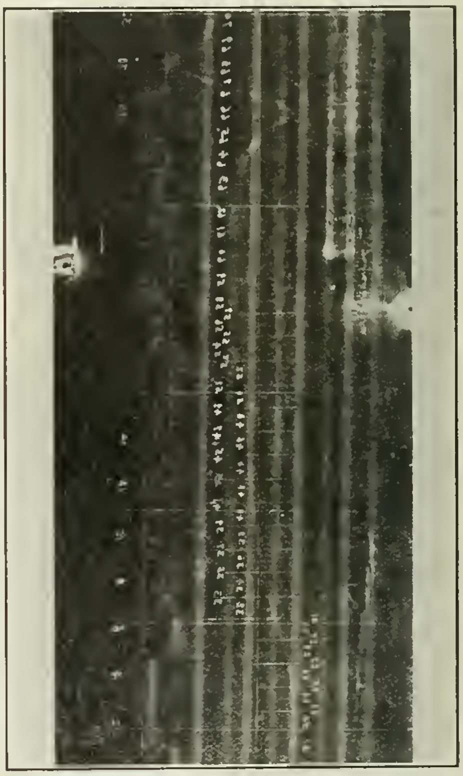

FIG. 9 RECORD OF PIEZOELECTRIC GAGE OBTAINED ON FILM OF SOLENOID CHRONOGRAPH CAMERA

(The inclined line at the right of the illustration is the record.)

Fig. 7 is the film after exposure, showing the tuning lines and the jogs in the oscillograph line caused by the projectile passing through the coils. Tests have shown that this camera is capable of measuring time to within one-hundred thousandth of a second.

The solenoid chronograph is being used successfully to measure the retardation caused by the resistance of the air acting on projectiles of various forms. As also shown by the air-stream experiments previously referred to, the resistance is very greatly affected by the "yaw" of the projectile or angle between its axis and the direction of motion of its center of gravity. Consequently the yaw in these air-resistance experiments is always determined by firing through a series of cardboards and carefully measuring the holes made by the projectile.

INTERIOR BALLISTIC EXPERIMENTS

For improvements in gun construction as well as improvements in propellant powder we must have accurate knowledge of what actually takes place when a gun is fired. It may be of interest to note that not more than 70 years have elapsed since the first successful attempts to measure the maximum pressure developed in a gun. Out of these attempts made by General Rodman, to whom we owe many other advances in ordnance construction, there was developed the modern crusher gage, some form of which is used at all testing grounds. This gage serves a very useful purpose, in that it gives a definite pressure reading and permits the setting of a definite pressure limit which must not be exceeded.

Comparisons of pressures indicated by crusher gages with velocities developed in the projectile, and with recoil energy given to the gun, have cast doubt upon the reliability of the reading of the crusher gage as a quantitative measure of maximum pressure. This doubt has been confirmed by experiments made at various times in which records of time-recoil were obtained in a free-recoiling gun simultaneously with records of crusher-gage pressure. From a good time-recoil record it is possible to get a time-acceleration record of the free-recoiling mass, and this is proportional of course to the time-pressure record.

Velocimeter. The instrument generally used to obtain the time-recoil record is the Sebert velocimeter and consists essentially of a vibrating tuning fork mounted in proximity to a smoked steel ribbon which recoils with the gun. The tuning fork, which is stationary, is fitted with a pointer placed in light contact with the ribbon. As the latter recoils with the gun it scribes a line on the ribbon, each wave of which corresponds to the natural time of the fork. A record made by this instrument is illustrated in Fig. 8.

Time-Pressure Gage. Various attempts have been made to develop a direct-reading time-pressure gage and one which would at the same time correctly represent the instantaneous pressures in the gun. Since the pressures in the gun are quickly applied and change in value quickly, the record obtained by any gage having relatively large moving parts is affected by the inertia of those parts. The results obtained with any gage depending for its action upon the crushing of metal are probably affected by the varying viscosity of the metal under varying speeds of crushing.

Quite successful gages have been constructed using springs instead of crusher cylinders, or in other words, straining metal within rather than beyond its elastic limit.

Piezoelectric Gage. In 1919 the Ordnance Department began an investigation of the possibility of constructing a pressure gage using quartz crystals, which have the property of developing a static charge when compressed. In coöperation with the Bureau of Standards, a gage of this type has since been developed and consists essentially of 12 or more quartz disks, which with metal separators are placed in a steel housing and subjected to pressure through a piston at one end. The gage proper is not larger than the crusher gage heretofore used, and is screwed into the "mushroom head" of the breech mechanism in the tapped holes provided for the former gage. The only change necessary in the gun is a means of leading a single wire connected with half the metal plates of the

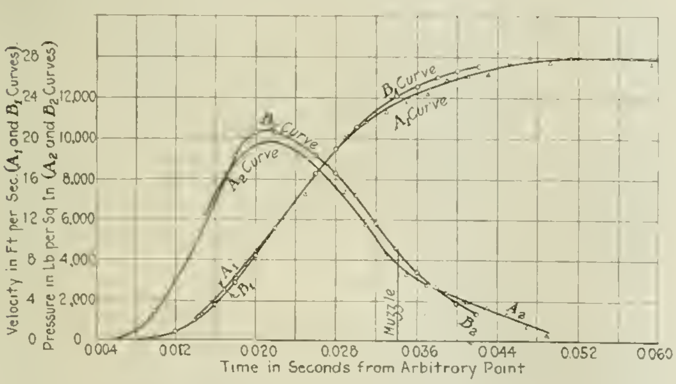

FIG. 10 VELOCITY-TIME CURVES AND CORRESPONDING PRESSURE-TIME CURVES AS DETERMINED BY RECOIL CONTACTS AND BY THE PIEZOELECTRIC GAGE

Curve A_1—Recoil velocity-time curve, recoil contacts.
Curve A_2—Pressure-time curve, computed from recoil contacts.
Curve B_1—Recoil velocity-time curve, computed from record of piezoelectric gage No. 1, using Bureau of Standards calibration of Nov. 18, 1922.
Curve B_2—Pressure-time curve, piezoelectric gage No. 1
If V = recoil velocity in ft. per sec. (Curve B_1) and P = pressure in lb. per sq. in., then $P = 7.417\ dv/dt$.

gage out through the breech mechanism. The other plates are grounded in the gage. To obtain a record with the gage, two other instruments are required, viz., a ballistic galvanometer and a rotating film camera fitted with a tuning fork to give timing lines. The camera actually used is that described above as forming a part of the solenoid chronograph and shown in Fig. 6. The ballistic galvanometer is so mounted that a beam of light from its mirror is deflected by the current from the gage at right angles to the direction of motion of the film.

When the circuit through the galvanometer is open, the charge developed on the quartz plates is exactly proportional to the pressure applied to the piston of the gage, or $Q = cP$, the factor of proportionality depending upon the dimensions, size of plates, etc. When the circuit is closed, the charge flows through it, the relation between the current and the pressure being as follows:

$$i = \frac{dQ}{dt} = c\frac{dP}{dt} \qquad [1]$$

The current flowing through the galvanometer subjects it to a torque

$$Gi = K\frac{d^2\theta}{dt^2} \qquad [2]$$

where G is the dynamic constant of the galvanometer, K its moment of inertia, and θ the angular deflection of the mirror. In writing this equation we neglect entirely the restoring torque of the mirror

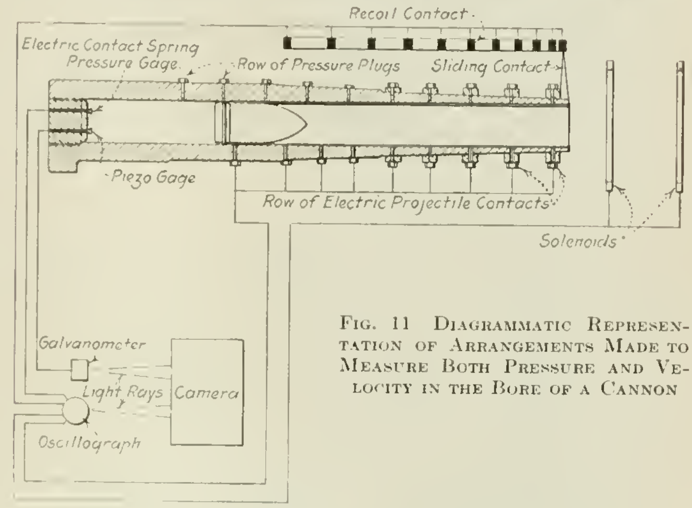

FIG. 11 DIAGRAMMATIC REPRESENTATION OF ARRANGEMENTS MADE TO MEASURE BOTH PRESSURE AND VELOCITY IN THE BORE OF A CANNON

mounting and the damping property of the instrument, both of which are small for a galvanometer of this type within the movement of the mirror with which we are concerned.

Combining Equations [1] and [2], integrating and solving, we obtain:

$$P = \frac{K}{Gc}\frac{d\theta}{dt} \qquad [3]$$

Our record on the film gives the data from which the displacement of the galvanometer as a function of time may be measured. From

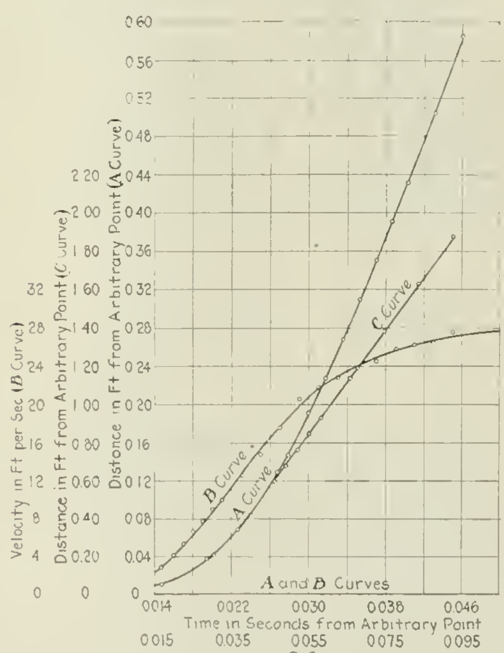

FIG. 12 DISTANCE-TIME AND VELOCITY-TIME CURVES DETERMINED BY RECOIL CONTACTS

Curve A—Distance-time curve for recoil (to 0.046 sec.)
Curve B—Velocity-time curve for recoil
Curve C—Distance-time curve for recoil (from 0.046 to 0.095 sec.)

Equation [3] we see that the slope of this curve is proportional to the pressure. Fig. 9 shows a record as obtained on the film of the solenoid chronograph camera. Fig. 10 shows in the B_1 curve the same record as plotted to another scale and the corresponding time-pressure curve B_2 obtained from it.

For the purpose of determining as accurately as possible with the new instruments available, the pressure and velocity at each instant of time during the firing of a shot, the Ordnance Department drew up a program of firing a 240-mm. howitzer, mounted so as to permit free recoil.

As shown in Fig. 11, the following data can be obtained at each round when the various contact points, time-pressure gages, etc., are made to register on the solenoid chronograph camera:

a Time of free recoil of the gun to any given point

b Time of passage of the projectile to any point in the bore

c Time of passage of the projectile to any desired number of points in front of the muzzle

d A curve of the deflection of the mirror of the ballistic galvanometer of the piezoelectric gage as a function of time

e Time the Curtis spring pressure gage reaches various degrees of compression.

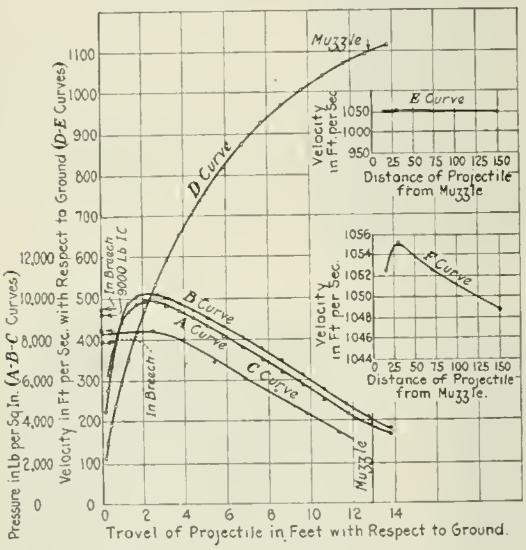

Fig. 13 Projectile Velocity-Travel and Pressure-Travel Curves as Determined by Various Methods

Curve A—Pressure-travel curve computed from recoil velocities given by recoil contacts.
Curve B—Pressure-travel curve, piezoelectric gage No. 1, Bureau of Standards calibration of Nov. 18, 1922.
Curve C—Pressure-travel curve from crusher gages of zero initial compression.
Curve D—Projectile velocity-travel curve computed from recoil velocities, assuming that the center of gravity of the powder has a velocity of one-half that of the projectile.
Curve E—Projectile velocity-distance curve (exterior) from solenoids.
Curve F—Curve E with velocity scale enlarged.
Note:—Projectile travel is estimated from recoil distance, assuming that the motion of the center of gravity of the powder is one-half that of the projectile and that the recoil is perfectly free.

The time of the actual firing of the electric primer which fires the gun is also recorded, and a connection is made by which the beginning of the motion of the projectile is recorded.

Now by plotting the distance-time curve for the motion of the projectile and differentiating graphically we may plot the velocity-time curve, and by treating this in a similar manner, we may plot the acceleration-time curve for the projectile. Knowing the weight of the projectile, this curve, when properly scaled, represents the accelerating pressure on the base of the projectile. If the frictional resistance is known to be small, as when the rotating band is removed from the projectile before firing, the last curve will represent closely the actual pressure on the base of the projectile at each instant of time.

In exactly the same manner we may plot the distance-time curve for the recoil of the gun and determine the pressure-time curve which causes it to recoil. Provided our contact mechanism is good and our time-recording instrument precise and reliable, pressure-time curves can be determined in this manner to any degree of accuracy desired by using a sufficient number of contact points.

This method, however, requires a special gun mount, special drilling of the gun, etc., which need a great deal of time to provide and set up. One of the secondary objects of these experiments with the 240-mm. howitzer is to determine whether any of the time-pressure gages available will reproduce the pressure curve given by the distance-time method.

Fig. 12 shows in A the recoil distance-time curve and in B the recoil velocity-time curve computed therefrom for Round No. 9 of this test. Fig. 10 shows in A_1 the recoil velocity-time curve as in Fig. 12 and the pressure-time curve A_2 computed therefrom. This figure also shows in B_1 the curve of deflection of the ballistic galvanometer connected with the piezoelectric gage.

As stated above, this curve is the integral of the pressures applied to the gage and the time, and to proper scale should be the same as the A_1-curve of the recoil contacts provided we omit frictional resistance. The B_2-curve of this figure results from differentiating the B_1 curve and is the time-pressure curve given by the piezoelectric gage. This particular round was fired with a projectile with a turned-down rotating band, so that the two curves, A_2 and B_2, should coincide. That they do not exactly coincide is believed to be due to errors in calibration of the piezo gage.

Fig. 13 shows the same curves as Fig. 10, plotted now to a scale of distance instead of time. The C-curve of this figure indicates the pressures given by copper cylinders screwed into the side of the gun at various points along the bore. It will be noted that the pressures they indicate are consistently low. In tests made using projectiles with rotating bands the pressures indicated by copper cylinders placed forward of the initial position of the projectile are invariably higher than those indicated by the other methods. In all cases the pressures indicated by gages placed in the powder chamber are lower than those indicated by the other methods. The higher pressure indicated by the copper gages used when a projectile with a rotating band is fired are believed to be due to the sudden application of the pressure to the piston of the gage. This sudden application does not take place when the band is turned down, permitting a gradient of pressure to exist, nor does it take place in the powder chamber where the development of the pressure is more or less gradual.

In the round described above, the pressure applied to the gun was determined by the recoil contact method and by the piezoelectric gage which was screwed into the breech block.

We could also have plotted the pressure computed from the projectile contacts and this would have been the pressure on the base of the projectile. However, it is rather difficult to get these contacts with the rotating band turned down.

Since the piezo gage measures actual gas pressure and the contact method accelerating pressure, the difference between the two is frictional resistance. The combination of these two methods therefore offers a means of determining the frictional resistance of a projectile during firing.

In the field of hollow-drawn forgings there have been very interesting developments lately both as regards their size and character. Recently there have been devised means for increasing the yield of gasoline from crude oil by the application of cracking methods. The oil is heated to about 875 deg. fahr. under 500 to 600 lb. pressure while circulating through tubes in a furnace, and flows to a large insulated cylinder where the completion of the cracking operation takes place. This cylinder, or reaction chamber, must stand heat, pressure, corrosion by sulphur in the oil, and be absolutely leakproof, for the gasoline under high pressure is well above its ignition point. The use of forged steel cylinders for this purpose has met with signal sucess.

A Babcock & Wilcox boiler building for the new Weymouth Station of the Edison Illuminating Co. of Boston has approximately 19,743 sq. ft., of heating surface and will furnish about 110,000 lb. of steam per hour at a maximum pressure of 1200 lb. per sq. in. The cross drum of this boiler is a forged steel cylinder of 48 in. inside diameter, $56^1/_2$ in. outside diameter and 34 ft. total length over the ends, which are closed in to take a 12-in. by 16-in. manhole cover. This is one of the largest hollow forgings ever made; the forged weight is 162,000 lb., requiring an ingot of 262,000 lb. to allow for scrap and losses. The billet was cut hot from a 78-in. octagon ingot, was stood on end and upset to about 96 in. in diameter, had a $23^1/_2$ in. core removed with a hollow punch, was expanded to about 50 in. in inside diameter, drawn on a mandrel to 45 in. inside diameter, $58^1/_2$ in. outside diameter, annealed, tested, machined inside and out, and after closing in is to be reannealed, have the throat machined to $11^3/_4$ in. inside diameter and the exterior of the head trued up.—John L. Cox in a paper before the American Iron and Steel Institute, as reported in the *Iron Age* for November 1, 1923.

The Gibson Method and Apparatus for Measuring the Flow of Water in Closed Conduits

By NORMAN R. GIBSON,[1] NIAGARA FALLS, N. Y.

The purpose of this paper is to elucidate a new method of determining the rate of discharge or quantity of water flowing in a pipe or other closed conduit, and to describe the apparatus used for the practical application of this method in testing the efficiencies of water wheels in hydroelectric plants. The procedure in the field is explained, as well as the manner of recording, delineating, and measuring the pressure-time diagram from which the discharge is calculated.

THIS is a new method of water measurement and it has required the invention of new apparatus for its practical application. If any apology is considered necessary for introducing it at this time when so many well-tried methods and devices are already in general use, it may be found in the fact that some important advantages have already been obtained through its application to the testing of water wheels, where the inconvenience and expense of any of the older methods would have been objectionable. These advantages have made it possible to make tests at frequent intervals, at slight expense, to determine the operating condition of water wheels without seriously interfering with their commercial operation. It may also be added that in point of accuracy, measurements by the new method have been found remarkably precise when tested in accordance with the dictum of Clemens Herschel, the distinguished hydraulic engineer that "The only standard water-gaging apparatus is a tank or reservoir. Weirs, orifices, venturi tubes and meters, and other water-gaging apparatus and methods can become truly rated only by comparison with tank measurements and thus thereafter competent to give reliable service."[2]

The method herein described makes use of two well-known principles, the first being Newton's second law of motion, sometimes referred to as the equation of impulse and momentum, and the second (attributed to Joukovsky) being a corollary of the first, namely, the relation between change of pressure and change of velocity of a column of water expressed in terms of the velocity of the pressure waves which are propagated during the change from one end of the column to the other. It has been in practical use for upward of three years. As a result of this experience, it may confidently be asserted that the method combines the qualities of accuracy, convenience, and economy, although it is not to be expected that the full extent of its usefulness can be determined until after a considerable period of time.

Field Work

Preliminary. Two essential conditions are required for the measurement of water by this method, first, the water must flow through a pressure pipe or other closed conduit; and second, means must be available for controlling the flow, such as a valve or turbine gates, at a point some distance from the intake. It makes no difference how large the conduit may be or whether the cross-section is of uniform area or not. The accuracy of the measurements, however, depends to some extent on the length of the conduit, and it is desirable that this should be at least 50 ft., preferably not less than 100 ft. The method does not apply to the measurement of flow in open channels.

It is evident, therefore, that not every hydraulic plant can be tested by this method. Fig. 1 shows a cross-section of a typical plant, the physical conditions of which are suitable for the simplest application of the method. Measurements of water flowing through more complicated waterways may also be made by using the differential application of this method, but for the present the discussion will be confined to the simple type here illustrated. In such a plant the water flows out of a forebay into a penstock at the lower end of which is a single modern hydroelectric unit comprising a turbine and generator equipped with a hydraulic governor. At the upper end of the penstock is a sluice gate or valve and at the lower end just at entrance to the turbine casing there is sometimes installed another valve. To set the unit in operation the turbine gates are opened by means of the governor and the water then flows through the penstock, turbine, and draft tube and is discharged into the tailrace. The unit is shut down by closing the turbine gates by the same means. The flow of water in the penstock is therefore under control at all times and the time taken in the opening or closing of the turbine gates may be varied at will by regulating the speed of the stroke of the governor, the

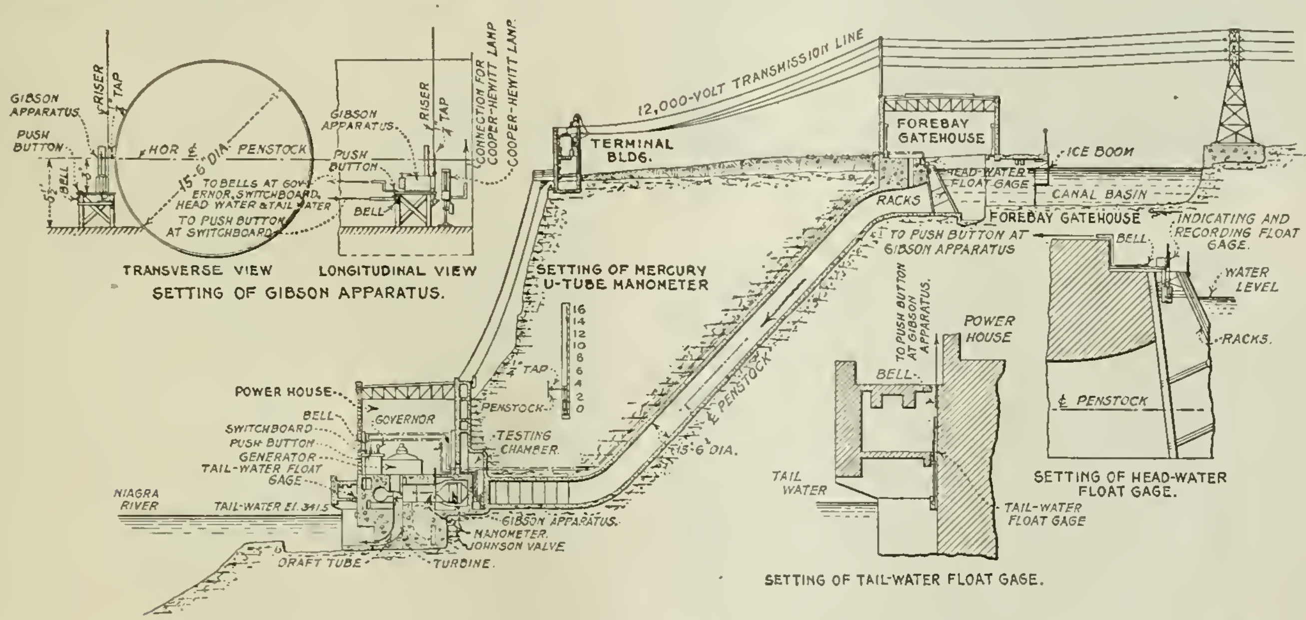

Fig. 1 Cross-Section of Typical Hydroelectric Power Plant Showing Location and Setting of Apparatus and Equipment for Efficiency Tests

[1] Hydraulic Engineer, The Niagara Falls Power Co.

[2] An Improved Form of Weir for Gaging in Open Channels. Trans. A.S.M.E., 1920.

Contributed by the Power Division for presentation at the Annual Meeting, New York, December 3 to 6, 1923, of The American Society of Mechanical Engineers, 29 West 39th Street, New York. Abridged. All papers are subject to revision.

operation of which may be accomplished either automatically or by hand.

The apparatus required for an efficiency test, parts of which will be described in detail later, comprise the following:

a A headwater indicating and recording float gage which will give an accurate record of the headwater levels during a test. The instrument for this work must be specially designed to make one revolution of the drum in about four or five minutes so that it will show clearly, to relatively large scale, any surges that occur in the forebay during or immediately following the closing of the turbine gates.[1]

b A tailwater float or staff gage for observing tailwater levels.

c The apparatus for obtaining pressure-time diagrams, which has been called the Gibson Apparatus,[2] and which is attached to the penstock at any convenient point by means of a ¼-in. connecting pipe as illustrated in Fig. 1.

d A pressure gage or piezometer for measuring the head acting on the turbine.

e Electrical equipment for measuring the output of the generator. It is assumed that the efficiency of the generator will have been previously determined.

f A signal system (usually electric bells) for communicating with the observers at the forebay, tailrace, pressure gage, Gibson Apparatus, and electrical instruments and with the operator at the governor.

The items enumerated above include, of course, not only the apparatus necessary to measure the water, but also the equipment for measuring the power output of the turbine and for determining its efficiency. The location and setting of the apparatus and equipment is shown in Fig. 1.

Procedure. The various operations to be performed in the field to obtain the data from which the final computations are made are as follows:

It is first necessary to obtain the physical dimensions of the pipe line from its intake at the upper end to the point of attachment of the Gibson Apparatus. When the penstock is made up of pipes of various sizes, the length and area of each size should be determined and where a variable section exists, as for instance, at a flaring mouthpiece, the lengths and areas of successive sections a short distance apart should be taken so that the whole may be properly integrated. The total length along the center line of the penstock from the apparatus to the face of the mouthpiece should be accurately determined and should check with reasonable accuracy the sum of the lengths of the various parts.

The personnel engaged at the various posts should be directed by one man who has no specific duties to perform in order that he may supervise all the operations from time to time and thus be able to review the work as a whole.

After checking the elevations of the zeros of the headwater and tailwater gages, testing the pressure gage for measuring the head on the turbine, setting up the apparatus and signal system and inspecting the unit to be tested, etc., the operations to be performed are as follows:

The unit to be tested is usually synchronized with other units in the plant and allowed to run on steady load at the desired point with the gates fixed for several minutes. In fixing the gates at the various percentages of gate opening where it is desired to determine the efficiency, it is important to have them perfectly steady so as not to set up disturbances in the penstock. For this purpose it is better to use the hand control which is usually supplied in a modern governor, but if this is not available various devices may be employed to lock the automatic control valve of the governor so as to hold the gates steady for a few minutes at a time until it is necessary to release them.

When everything is in readiness a signal is given, say, "2 bells," and at that moment observations are taken of the headwater and tailwater levels, pressure at entrance to the turbine case, gate opening, kilowatt output of the generator, voltage and amperage of exciting current, and the usual entries of time and other items worthy of note.

After these observations have been made for a period of two minutes, or longer if necessary, the operator of the Gibson Apparatus sets this instrument in motion and then gives a signal, say, "1 bell," at which all the observers mark their records and the governor attendant operates the governor so that the turbine gates are gradually and gently closed. The duration of this closing action will depend upon the length of the penstock. If it is short a quite rapid closure, say, in three or four seconds, may be made. If the penstock is very long the duration of closure may take perhaps more than a minute. In a penstock from 200 to 400 ft. long a satisfactory closure may be made in from eight to sixteen seconds.

As the turbine gates close, the power output of the unit of course diminishes and its load is picked up by the other units operating in synchronism with it. When the gates are fully closed the unit continues to revolve at normal speed, being then operated as a synchronous motor by the current in the circuits to which it is connected.

The object of closing the turbine gates in this manner is to produce a change of pressure in the penstock which will occur when the flow of water therein is brought to rest. The Gibson Apparatus (which will be described in detail later) is devised to obtain a precise record of this change of pressure in the form of a diagram of which Fig. 7 is a typical example. On this diagram *A* marks the beginning of the record. At *O* the pressure begins to rise as the turbine gates are being closed. At *K* (the determination of which will be explained later) the gates are fully closed and from *K* to *C* the column of water is being restored to equilibrium in a series of damped harmonic oscillations or waves. At *Z* there is an interval of time sufficiently long to allow these oscillations to subside, and then at *F* there is a short record which registers the pressure in the penstock under the then existing hydrostatic conditions. It will be observed that narrow vertical spaces *D* where the record has been obliterated occur on the diagram at regular intervals. These intervals are records of time usually one second apart, or, speaking more correctly for reasons which will be explained presently, each pair of intervals measures exactly two seconds.

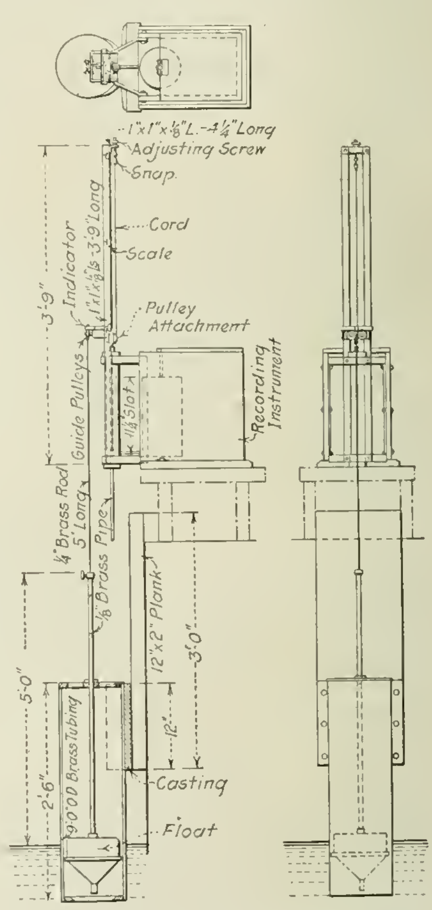

Fig. 2 Headwater Recording Gage

Upon the completion of this record—called the "pressure-time diagram," or more simply "the diagram"—a signal is given to the observers which terminates the "run" as the operations of the test at each load are called.

The unit is then loaded up again to the next point desired and everything is placed in readiness for the next run. These operations are repeated as often and at as many points as are desired. Usually it will be found that from 10 to 12 diagrams ranging from half-gate to full load will be sufficient. Each run will require from 10 to 15 minutes, so that if no difficulties arise the field work for one unit may be completed in from two to three hours, exclusive of time required in the preparation for the test and for the leakage test which will now be described.

Leakage Test. In this method of water measurement only the

[1] When differential diagrams are used, a simple staff gage is sufficient for determining headwater levels.

[2] Method and apparatus patented, Canada 1919 and 1920, United States Oct. 13 and Nov. 22, 1921. Patents applied for in foreign countries.

flow actually shut off is measured. If the whole flow is shut off, no other operations than those described above are necessary. It usually happens, however, that the valve to be closed or the turbine gates themselves are not perfectly tight and after closure some water leaks through. The measurement of this leakage is not included in the diagram and must of course be separately determined and added to the quantity calculated from the diagram to obtain the total discharge. In a new modern unit the leakage is relatively quite small and its amount can be quickly and precisely determined in a number of ways. If the total discharge of the turbine is 100 cu. ft. per sec. and the leakage is 20 cu. ft. per sec., an error of 5 per cent in determining the leakage results in a final error in the measurement or discharge of only about 0.1 per cent. Usually, however, the leakage may be determined with much greater accuracy than this and often it can easily be measured precisely. When the leakage is relatively large, greater care in its determination will be required if precise results are desired.

It is not intended to lay down any definite rules by which the leakage factor must be found. The essential point is that it should be determined with sufficient precision in a given case, and it may safely be left to the common sense and resourcefulness of the engineer in charge of the test to do this in a satisfactory way.

Apparatus

Fig. 1 is a general drawing showing the setting and arrangement of the apparatus and equipment, and also some details of the minor parts.

The headwater recording gage which is shown in Fig. 2 has been designed specially for use in the simple application of this method of testing. It comprises a brass float 8 in. in diameter surrounded by a well consisting of a short piece of 9-in. brass tubing mounted on a heavy plank which may be fastened in place in any convenient manner. A rod from the float is connected to a crosshead which slides between guides and is connected through a reducing block and tackle to a brass pencil as illustrated in Fig. 2. The vertical travel of the pencil may be made to correspond in any desired ratio to the variation in level of the float, but in the instrument here illustrated the pencil moves one-half the vertical travel of the float. The supports for the rod and pencil are attached to a box, the front end of which has been left open. This box contains a drum about 6 in. in diameter and 12 in. high which is operated by means of a spring motor and gearing designed so that the drum will make one revolution in from 3 to 5 min. For each run a sheet of coated paper 18 in. long by 11 in. wide is securely wrapped around the drum and receives the impression from the brass pencil which rests lightly on the surface of the paper and thus records to half-scale the motion of the float in the headwater. A clock mechanism and electric battery and magnet located inside the box operate a pointer which makes a mark every five seconds on the coated paper near its lower edge. The record of headwater level is thus combined with a record of time.

The signal system may be left to the discretion of the engineer in charge of the test. Usually a system of electric bells will be sufficient, preferably a system operated with magneto because the bells may then be connected in series. A telephone system of signaling is quite satisfactory and very convenient when the distances between observers are great. When distances are short and when conditions will permit, a horn or whistle may sometimes be used.

The apparatus for obtaining the pressure-time diagrams will need to be described in detail. Photographs of the apparatus are shown in Figs. 3 and 4. It is also shown diagrammatically in Fig. 5, to which the letters in the following description refer.

P is a pipe or conduit in which the fluid, the rate of discharge of which is to be measured, is assumed to be flowing in the direction indicated by the arrow, and V is a valve or other means, such as turbine gates, for interrupting the flow of the said fluid.

The apparatus is attached to the pipe P on the upstream side of the valve V at some point B by means of a short small pipe C in which a valve is placed near B. D is a glass tube of as nearly as possible uniform bore joined to the pipe C and to the riser pipe E—also as nearly as possible of uniform bore—by means of stuffing boxes and glands at F and G. Together the pipes C and E and the tube D form a U-tube. A quantity of mercury is poured into the top of the riser E or is otherwise introduced into the U-tube so that when the valve at B in the pipe C is opened the mercury column is depressed in tube D and rises in the riser pipe E in proportion to the pressure existing in the pipe P. Needle valves, as indicated, are provided at points 3, 4, and 5 for adjusting the height of the mercury in the tube D and for expelling air, etc. For higher heads an enlargement of the tube C is made to facilitate filling the U-tube with mercury. The difference in level between the tops of the mercury columns in D and E is then a measure of the pressure existing in the pipe P. Changes of pressure in P produce corresponding changes of level of the tops of the mercury columns in D and E.

Opposite the tube D is a box H containing a photographic lens

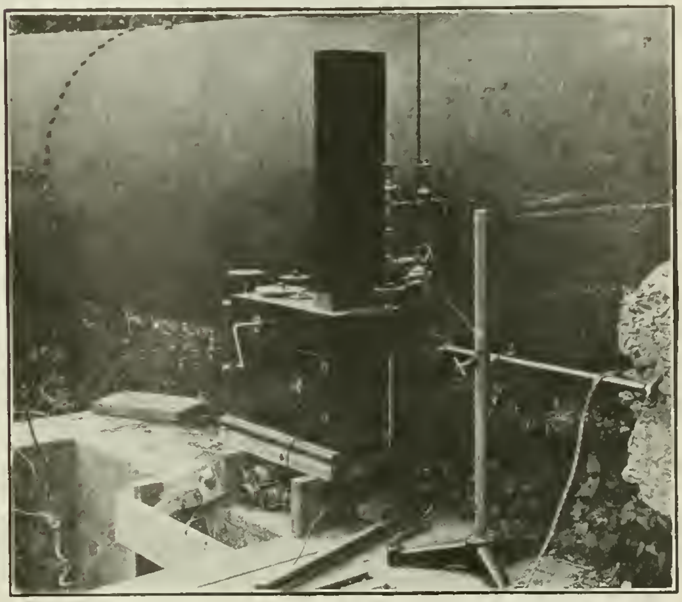

Fig. 3 Front View of Gibson Apparatus

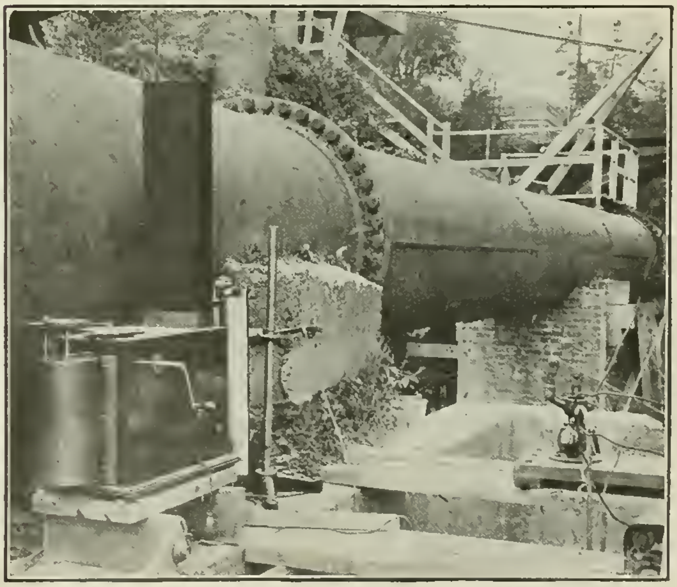

Fig. 4 Rear View of Gibson Apparatus

and shutter J and a pendulum K. At the top of the pendulum is a setscrew and bar L for adjusting the length of the pendulum. The pendulum cord is thickened at its lower extremity, as shown, and the whole is enclosed in an upward extension of the box.

In the end of the box opposite D is a slot about as long as the tube D and narrower than the diameter of the tube. Between the box and D is a shrouding M which excludes the light, except that which enters through the tube D from the side directly opposite the slot referred to. This shrouding partly surrounds the tube D and has fastened to it, crosswise of the tube D, two fine cross-wires 1 and 2, a measured distance apart.

At the other end of the box is an opening in which a ground

glass may be placed for observing a photographic image of the tube D cast on the glass by means of the lens J. The ground glass is for observation purposes only and may be removed and replaced by the revolving drum N set in a lightproof holder which may be attached to the end of the box H by means of guides and thumbscrews.

On the outside surface of the revolving drum N there may be attached, as required and in a dark room, a sensitized photographic film on which the pressure-time diagram is to be recorded. Photographic paper may be used, if desired, in place of the film, but usually will not give as good results on account of the shrinkage of the paper when developed.

On the side of the holder adjacent to the box there is a narrow slot, O, lengthwise of the holder, which may be opened or closed by means of the shutter A. This shutter is shown in detail in Fig. 5 and consists of a cylindrical bar through which a slot has been

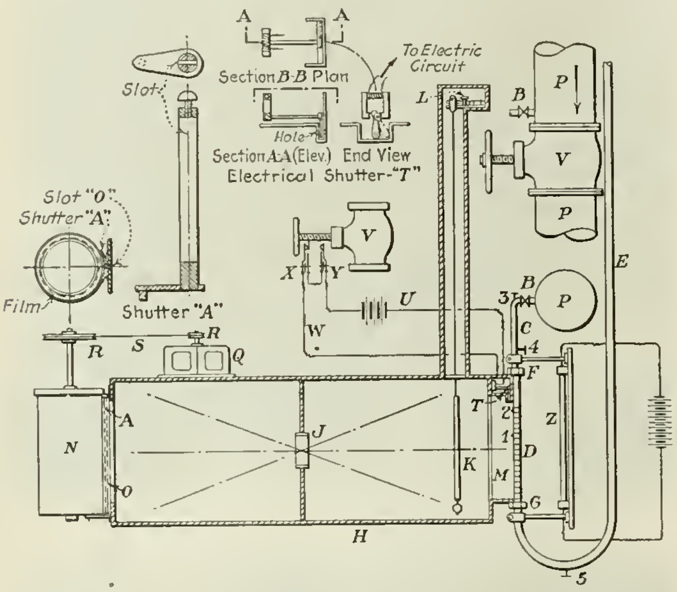

Fig. 5 Diagrammatic Sketch of Gibson Apparatus

cut. The bar fits snugly in a hole bored in the casting supporting the lightproof holder and may be revolved so that the slot in the bar will come opposite the slot O in the holder when it is desired to allow the light to pass through to the film on the drum N, or it may be turned 90 deg. from this position when it is desired to shut off the light from the film. The shutter may be held in either position by means of an arm attached to the bar and secured by a spring attached to the holder.

The drum N is revolved at uniform speed by means of a mechanical motor Q through pulleys R and belting S or through other means, its speed being regulated by a governor and flywheel.

In case the apparatus cannot be used in daylight, an electric mercury-vapor lamp Z or other means of illumination will be required.

The use of the auxiliary electrical shutter T shown in detail in Fig. 5 has been discontinued, and for the purposes of the present paper it will be unnecessary to refer again to this part of the original design.

In setting up the apparatus for the purpose of making differential diagrams, the top of the riser instead of being left open to the atmosphere is connected by means of a pipe, preferably about 1 in. in diameter, to a piezometer opening located at some suitable distance upstream from the point B. Mercury is poured into the U-tube until its surface in the glass tube D is at the required height and the remainder of the piping system is filled with water, care being taken to see that all air is excluded and that all joints are perfectly tight.

The Pressure-Time Diagram

Recording the Diagram. The manner of using the apparatus and of making a pressure-time diagram is explained as follows:

The equation from which the rate of discharge is determined is $Q = KA/SF$, in which Q is the discharge in cubic feet per second, K the constant of the apparatus, S the time scale of the diagram, and F the pipe or conduit factor.

The pipe factor F of a simple pipe of uniform cross-section, such as the pipe P, Fig. 5, is the length from the point B to the upper end of the pipe divided by its area. When the pipe is made up of several lengths in series l_1, l_2, l_3, etc., of different areas a_1, a_2, a_3, etc., then the pipe factor F is

$$\sum \frac{l}{a} = \frac{l_1}{a_1} + \frac{l_2}{a_2} + \frac{l_3}{a_3}, \text{ etc.}$$

The pipe factor is determined first.

Next the ratio R of the areas of tubes D and E is obtained. For this purpose a calibrating rod is provided with the equipment. This rod is made up of several lengths of copper wire surrounded by, but insulated from, a small brass tube or sheath. These lengths may be screwed together and are so designed that connection is made between each length of copper wire without making contact with the brass sheath.

For the purpose of calibrating for R the Gibson Apparatus is set up either in the laboratory or in the field at the place where the tests are to be made and the tubes are filled with mercury as usual. By means of a small pump, or by admitting pressure in successive increments from the penstock, the mercury is depressed in D which causes it to rise in E. If the work is done in a laboratory, intermediate sections of the riser are removed so that the part of the riser E in which the mercury changes position when depressed in D is the same part as that in which the change will take place when the apparatus is attached to the penstock. It is obvious of course that when the tube D is attached to a pipe or penstock the static head existing in the pipe will force the mercury to a higher level in E and additional lengths of riser are necessary. The changes of level corresponding to changes of pressure during a test then take place in the glass tube and the sections of riser which have been calibrated. In practice it will be convenient to attach the apparatus at some point on the pipe line where the head will not be so great as to require an excessively high riser.

The calibration is then made by wrapping a film on the drum in the usual way and exposing a short section of it at a time, as hereinafter described, so as to obtain a record of the elevation of the mercury in tube D at different stages, and at each stage the calibrating rod is inserted in the top end of the riser E until contact is made between the wire in the rod and the mercury. A bell and some batteries are connected in circuit with the calibrating rod and the riser so that when contact is made between the rod and the mercury the bell rings. By this means it is possible to determine when the rod is first touching the surface of the mercury. The distance from the top of the riser to the surface of the mercury is then read on the vernier attached to the calibrating rod and recorded. After a number of exposures have been made with the mercury depressed to various points in the tube D and the corresponding position of the mercury in E is determined, the film is removed from the drum and developed and a print made as illustrated in Fig. 6. The record thus obtained when related to the height of mercury in the riser E gives the ratio of the change in E for a given change in D. This method of calibration also includes any correction that might be necessary for parallax or variation in scale.

When increases of pressure occur in pipe P it is evident that the mercury in D will fall $1/R$ times the distance it rises in E, and the total change of pressure in feet of water will be $^1/_{12}[M(R + 1) - 1]$ times the distance in inches the mercury falls in D, where M is the specific gravity of mercury. Similarly, when decreases of pressure occur in P the mercury will rise $1/R$ times the distance it falls in E, and the total change of pressure in feet of water will be $^1/_{12}[M(R + 1) - 1]$ times the distance in inches the mercury rises in D. When the apparatus is connected to the pipe P for the purpose of making differential diagrams as described in a previous paragraph, the total change of pressure in the pipe P in feet of water will be $^1/_{12}(M - 1)(R + 1)$ times the distance in inches that the surface of the mercury changes in the tube D. The sizes of the tubes D and E for any particular case are selected so that the total motion of the mercury in D is limited to the length of the tube D. A record of the position of the top of the mercury column in the tube D during any time is therefore a record of the

pressure existing in the pipe P during that time. When the flow of water in the pipe P is interrupted, a change of pressure occurs. The change of pressure affects the level of the mercury column in tube D as already mentioned, and a record of this change of level is obtained as follows:

The lens J having been adjusted and permanently fixed so that a clear image of the top of the mercury column is projected on the ground-glass screen at the end of the box, the latter is permanently removed so that the film holder may be inserted in the guides. the mercury column is photographed on the revolving film by the means above described, thus furnishing a record of the change of pressure that took place in the pipe P as the flow was shut off.

During this operation the pendulum K keeps swinging to and fro, and on account of the enlargement of the cord already mentioned, the light passing through the tube above the mercury is cut off at each swing of the pendulum. This causes a break in the record on the film at regular intervals corresponding to the time period of the swing of the pendulum, which is usually adjusted

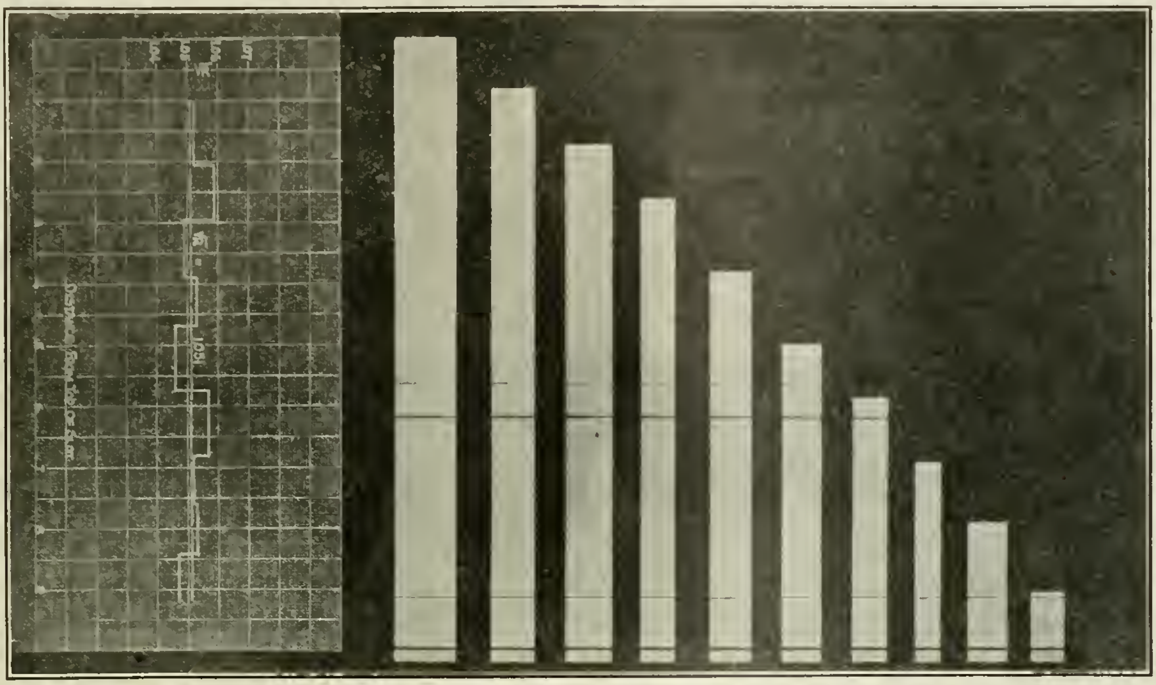

Fig. 6 Typical Calibration Diagram

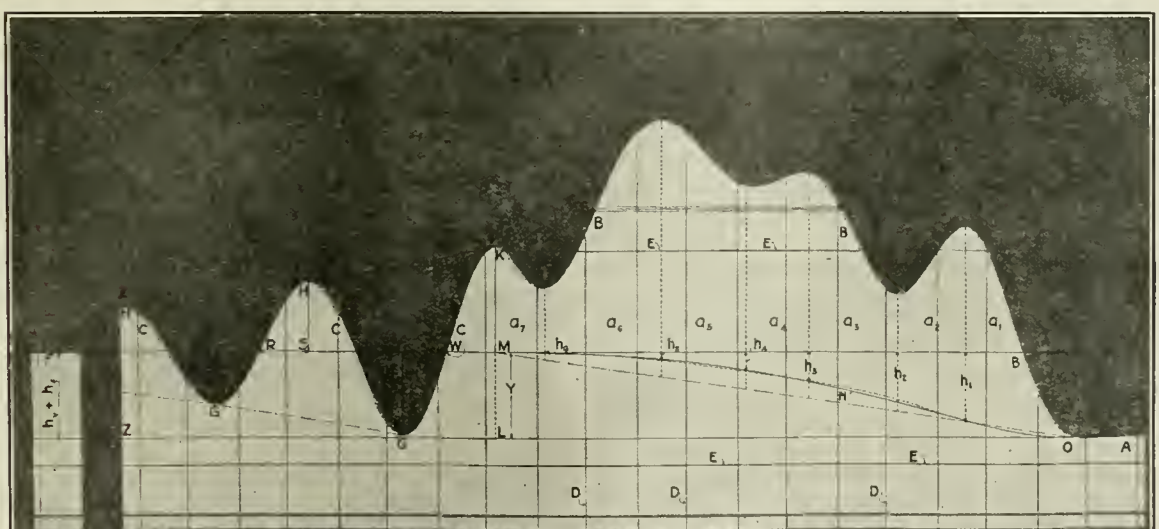

Fig. 7 Typical Pressure-Time Diagram After Delineation

A sensitized photographic film is wrapped around the drum N and fastened in place, the belting is slipped over the pulleys, and the motor wound up ready to start.

When all is ready the shutter A attached to the film holder is opened, the motor Q is started, and, just prior to the action of interrupting the flow in pipe P, the shutter of lens J is opened and the pendulum K is set in motion by pressing the pneumatic bulb attached to these parts. At this moment the flow in pipe P is gradually interrupted by means of the value V or by any other means. As the flow is being interrupted, the rise of pressure produced thereby causes the mercury column in the tube D to move downward. The amount of its depression is a measure of the change of pressure in the pipe P, and the motion of the top of to exactly one second. If the pendulum is not centered exactly with the slot, the intervals between breaks in the record will be alternately long and short. For this reason, as explained earlier, it is better to use each pair of intervals which will exactly measure two seconds.

After the flow has been completely shut off, the oscillations of the mercury column are recorded for a few seconds. After the oscillations have ceased and quiescent conditions exist in the pipe P, a short exposure is made to obtain a record of the static pressure in that pipe. Then the shutters are closed, the film removed and developed, and prints made. The result is shown on the typical pressure-time diagram, Fig. 7, on which the line *ABBKCC* represents the varying level of the top of the mercury column in tube

D. The D-lines are the breaks in the record at regular intervals caused by the swinging pendulum and the lines E,E are the photographs of the cross-wires 1 and 2 shown in Fig. 5, which are a measured distance apart, and from which the scale (usually exactly full size) of the diagram is shown. The edge F is a record of the level of the top of the mercury column corresponding to the static pressure in the pipe P.

Delineating and Measuring the Diagram. The diagram, Fig. 7, having been obtained in the manner described in the foregoing section, is treated as follows. It will be assumed for simplicity in explaining the calculations that the gates were perfectly tight when closed so that the flow was completely shut off when the diagram was made. The numerical example which will be given later will include the leakage factor.

1 Horizontal lines are drawn across the diagram, coinciding with lines F and A, respectively. If A is wavy due to slight variations in pressure of the water flowing in the penstock, the mean position between crest and valley of the wave may be used.

2 As the diagram is produced by means of an exposure through a narrow slot in the film holder, the width of slot will cause the diagram to be slightly larger than it would be if drawn by a point or by exposure through a slot of infinitesimal width. To correct for this lines may be drawn as shown at B,B and C,C at a distance equal to the width of slot from the edges of the pressure line so that when thus drawn these lines, together with the other edges of the diagram, delineate the pressure line that would be drawn if the slot were of infinitesimal width. A little study will make it clear that the width of slot is drawn only on either the right-hand or left-hand edges of the diagrams but not on both, depending on the direction of rotation of the drum. If desired, this correction for width of slot may be made by simply multiplying the width of the slot by the sum of the vertical heights of the corresponding edges of the pressure line. Usually this will be more satisfactory.

3 The point K which marks the end of the diagram, or more specifically the end of that part of the diagram which represents the impulse produced during the closure of the gates, is determined from the record C,C of the oscillations of the mercury column in the apparatus which occur after the turbine gates have ceased to move. These oscillations or waves are of uniform periodicity like the oscillations of a pendulum, and the horizontal distances measured in time intervals between the vertical lines passing through the peaks of the waves as from H to H and G to G are equal. The positions of the vertical lines passing through the peaks of the waves at H,H, etc., may be determined in several ways, such as by inspection or by the intersection of tangents to the points of inflection of the wave line.

4 The end of the diagram is at the beginning of the first regular wave nearest AA as at HK, and the position of K is determined by measuring back from W the point where the wave passes the neutral line FM,[1] a distance equal to RS. The position of the vertical line through K may also be found by marking off from the peak of the nearest wave a horizontal distance equal to one wave length HH. A vertical line KML is drawn through K intersecting the line F produced at M and the line A produced at L.

5 The point where the pressure line B departs from the line A is marked at O.

6 A straight line is drawn from M to O.

7 A number of vertical lines are drawn from the pressure line BB to intersect the line OM and the areas a_1, a_2, a_3, a_4, a_5, a_6, a_7, enclosed by these lines and corrected for width of slot, are measured by planimeter or by scaling in square inches. The sum of these areas will be called A_1.

8 The distance LM, which is a measure of the sum of the friction and velocity heads, is measured in inches and called Y.

9 Trial and error are now used to locate the line ONM which eliminates from the gross area the area produced by the recovery of friction and velocity heads.

As a first assumption the straight line from O to M may be taken, but usually it will be found easy to estimate by inspection the approximate position of the line ONM so that only one correction will be necessary.

$$\text{Let } P_1 = \frac{a_1}{A_1}, \qquad P_2 = \frac{a_1 + a_2}{A_1}, \qquad P_3 = \frac{a_1 + a_2 + a_3}{A_1}, \text{ etc.}$$

and let $h_1 = Y(1 - P_1)^2$, $h_2 = Y(1 - P_2)^2$, etc. Having determined the values of h_1, h_2, h_3, etc., from these equations, a point is located on the line separating the areas a_1 and a_2 or this line produced by measuring down vertically from the line FM produced a distance equal to h_1. A distance equal to h_2 is measured down vertically from the line FM produced on the line separating the areas a_2 and a_3. Similarly a distance equal to each of the values h_3, h_4, etc., is measured down from the line FM produced on the respective lines separating the areas a_3, a_4, etc. The points so plotted are then joined together, forming a line from O to M. If the line so plotted fails to coincide with the assumed line, a second trial is made using the new line in place of the one first assumed and proceeding as before. In this manner a base line ONM is found such that when the values of h_1, h_2, etc., are calculated as before but using the new areas a_1, a_2, a_3, etc., above the line ONM, the line joining the ends of h_1, h_2, etc., will coincide with ONM.

10 The area of the diagram delineated by the line $OBBKMN$ is called A and is a measure of the rate of discharge or quantity of water that was flowing in the conduit at the moment the gates began to close.

In practice it will sometimes be necessary to correct the area A for the effect of special conditions or disturbances such as surges in the forebay, gate well, or surge tank at the entrance to the conduit. This is readily done by observing or recording the height and duration of such surges and subtracting a corresponding area from the area A. Flow measurements may also be made by obtaining two diagrams similar to Fig. 7 simultaneously at different points along the conduit a known distance apart, the difference between the net areas of these diagrams adjusted to the same scale being used in place of the area A. Satisfactory results may also be obtained by using the differential diagram already referred to and illustrated in Fig. 8, which records only the difference in the changes of pressure that occur at two points on the pipe line. In these cases the pipe factor F for that portion of the pipe between the two points only will be used.

In the complete paper the principles and theory on which the method is based are examined, as well as the experiments which have been carried out to determine its accuracy in practical cases. In one of the two appendices will be found a complete typical example and a discussion of some of the various factors and special problems which may sometimes require consideration; in the other are given the results of tests made at Cornell University to determine the accuracy of the method.

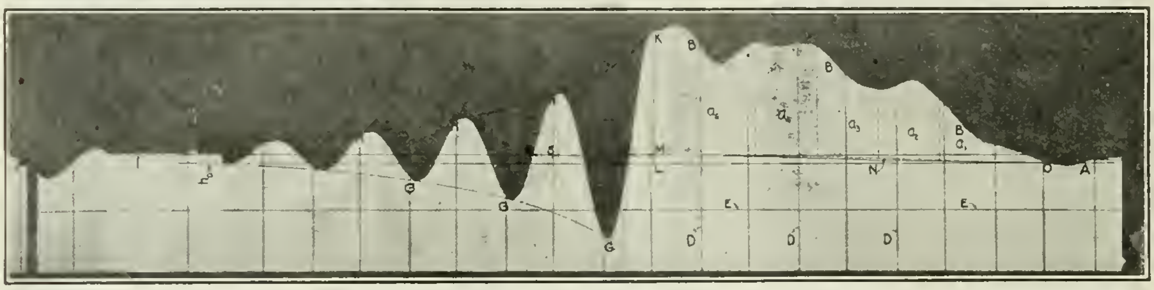

Fig. 8 Typical Differential Pressure-Time Diagram

[1] The neutral line is not always horizontal or coincident with F. See numerical example in Appendix No. 1 to the complete paper.

The Margins of Possible Improvement in the Central-Station Steam Plant

By ERNEST L. ROBINSON,[1] SCHENECTADY, N. Y.

The maximum attainable efficiency of the ideal heat engine is discussed, and the circumstances which limit it, in order to point out the various margins available for improvement along different lines. The arrangement of the circulating systems is considered and, after noting the ideal arrangement, practical layouts are taken up. The advantages of the mercury turbine and the steam-extraction cycle are emphasized, and the great increase in capacity rating which has been made possible by purely thermodynamic improvements is noted.

MANY influences are tending to force manufacturers of power to use the greatest care in the layout of their plants in order to obtain the best possible economy of operation. The greatly diversified inventions requiring the use of electricity have much increased the demand for it. Existing plants are more and more pressed to the limit of their capacities and must get the largest output from the available equipment. Increasing costs of coal continually tend to emphasize the importance of the fuel charge in the total costs of operation, and point to the necessity of greater economy in its use. And a sentiment is growing more and more manifest that a high public spirit and the interests of the community require an economical use of natural resources.

It is appropriate, therefore, to take stock of the processes and methods available for improving steam-plant efficiency. The engineering periodicals exhibit a great interest in these questions and a large variety of improvements have been suggested. Usually the authors have devoted themselves to the careful and ingenious application of one or several methods of improving efficiency and have worked out the practical application of their ideas in particular cases. The purpose of the present article is to run over the whole field in a very general way, and to point out the limiting efficiencies attainable and show the lines along which the greatest margins for possible improvement lie. At the outset, then, practical and mechanical limitations will be disregarded in order to go first to the theoretically best economy. Fortunately this may be done in plain engineering language without the use of complicated mathematics. When this has been done it will be appropriate to discuss briefly the various difficulties in the way of going the limit at once. Such speculations bring up very interesting problems in thermodynamical mathematics, which have, nevertheless, been avoided as far as possible.

In the case of any particular installation the correct procedure would, of course, be to start with good practice and make such improvements as can be shown to be desirable. The object of the present paper will have been accomplished if, starting from the more remote ideal, it directs attention to the whole field open for selection and thus enables a more valuable choice to be made as to the best line of development to apply in a particular case.

The Ideal Conversion of Heat Energy

Fundamentally conceived, the steam plant is simply a heat engine for converting fuel into salable power. The textbooks outline certain theoretical facts about heat engines which it is convenient to recall at this time. A heat engine receives heat from a hot source, does work, and rejects heat to a cold receiver. The process of combustion may be considered as the hot source and the condenser as the cold receiver. Heat is directly convertible into other forms of energy at a fixed theoretical rate known as the mechanical equivalent of heat or the heat equivalent of electric energy. If the ideal heat engine could convert all of the heat into work at this rate it would be necessary to reject the working substance devoid of all heat content, that is, at absolute zero. A working substance to carry the heat is of course essential. If, at any time, energy is reclaimed from the working substance, without other heat exchange, its availability to do work has been decreased a corresponding amount, that is, its absolute temperature has been changed. In fact, this idea is the whole basis of the definition of the thermodynamic scale of temperature. Since the temperature of a condenser can hardly be lowered to absolute zero, it is necessary for heat engines in general to do work, even under ideal circumstances, at an efficiency far less than unity. This efficiency is represented by the actual temperature drop of the working substance divided by what the drop might be if all heat were abstracted, that is, the initial absolute temperature. This is the well-known Carnot-cycle efficiency and also the efficiency of any reversible engine.

As this idea of a reversible engine will come up again, it is well to recall it a little more carefully. It really must be the ideal engine because, if any other engine which might be thought more efficient—so that for a fixed amount of work done it has a smaller heat turnover—were used to drive the less efficient reversible engine as a heat pump, such a supposition would enable two isolated machines working together to have a net turnover of heat from a cold to a hot source. Such a condition is contrary to all experience, and the reversible engine with the Carnot efficiency is thus vindicated as the ideal engine. Furthermore, the textbooks go on to show not only that the Carnot efficiency cannot be exceeded, but that any cycle including an irreversible process is necessarily less efficient. An illustration may help to recall this point.

The transfer of heat from a furnace at 2000 deg. fahr. to a boiler at 400 deg. fahr. is an irreversible process. Heat cannot be caused to flow by itself from the boiler to the hotter furnace. As a result of the decrease in temperature the availability of the heat energy in the steam at boiler temperature to do work is very much less than the theoretical availability of the same amount of heat energy in the furnace at the temperature of combustion. On the other hand, if the boiler absorbed the heat of the furnace at furnace temperature, such a process would be reversible, and would enable the steam to work with the higher thermodynamic efficiency which the high temperature would permit. In fact, the idea of availability to do work is synonymous with thermodynamic efficiency, and this idea of loss of availability or thermodynamic efficiency in connection with the irreversible step is the important thing to note at this time. Hence it is well to recall the various types of reversible process.

The Carnot cycle is made up of an isothermal expansion and an adiabatic expansion, followed by an isothermal compression and an adiabatic compression. The isothermal process or heat exchange without alteration of temperature can, of course, be worked either way since no temperature drop is involved. The adiabatic process is reversible because it simply means no heat exchange to the outside at all but simply a conversion of internal or heat energy into external or work energy. Ideally, the isothermal is infinitely slow and the adiabatic is correspondingly sudden in order to be reversible.

There is also the regenerative process in which all heat that passes out of the working substance during cooling is transferred at its own temperature to an auxiliary contraflow substance, so that it may be restored at its own temperature during a similar return process. This requires the infinite slowness of the isothermal and the supposition of a perfect contraflow heater always in contact with the working substance, so that the temperature differences between the working substance and the auxiliary substance are always infinitesimal.

Temperature Limits

Certain very elementary conclusions are possible at once from this review of simple thermodynamic principles. It is desirable to have as cold a receiver as possible, and since there are practical limits to this coldness, it is also desirable to have the source of heat at as high a temperature as possible in order to give the widest possible operating range. These are the things that must be kept in mind when deciding on the efficiency of the ideal process.

With steam as a working substance and modern turbine con-

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[1] General Electric Co.

Contributed by the Power Division for presentation at the Annual Meeting, New York, December 3 to 6, 1923, of the AMERICAN SOCIETY OF MECHANICAL ENGINEERS. All papers are subject to revision.

struction it has been found that vacuums corresponding to temperatures between 70 deg. and 80 deg. fahr. are the best that can be obtained with the cooling water available. Of course, it is imaginable that during an Alaskan winter a turbine might be made to exhaust into an air-cooled condenser at a temperature well below 0 deg. fahr. Obviously in such a case the suitability of steam as a working substance would have to be considered in addition to the mere degree of coldness available.

Likewise, at the other end of the process it happens to be far easier to produce high temperatures than to utilize their advantage, because, in the case of steam, the vaporization at a high temperature cannot be accomplished without confinement at an excessive pressure. Thus it is evident that the working temperature range is hedged around by various practical considerations which will need special consideration, and this will be given presently.

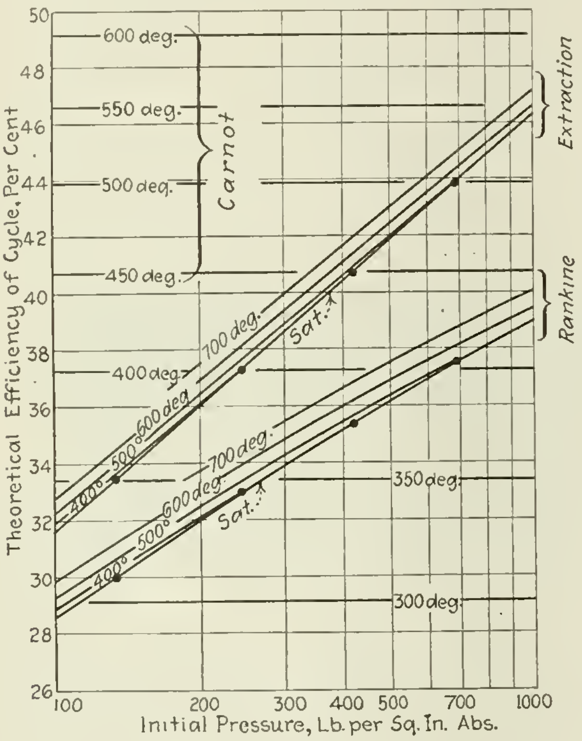

Fig. 1 Theoretical Efficiencies of Steam Cycles
(Based on Goodenough, 1917. Curves are for various initial total temperatures, deg. fahr., as indicated. Back pressure, 1 in. Hg.)

The Thermal Processes

It is next important to consider the thermal processes and how closely they may be made to correspond with the ideal arrangement, that is, what sort of cycles can be used to the best advantage. It has been pointed out that the thermal processes should be either isothermal, adiabatic, or regenerative, that is, in every case reversible. Beginning at the furnace, the fuel and air are brought together in the presence of heat. Combustion takes place and more heat is liberated. This is absorbed by the boiler and carried to the engine by the working substance. Finally such heat as has not been converted into work is rejected to the condenser. But in addition the burned gases escape up the stack.

The Ideal Furnace

If, for the present, attention is confined to the furnace, it is plain that all the substance, fuel and air, which goes on to the grate and is heated must, in exactly the same quantity, disappear up the stack. Furthermore these substances which start at atmospheric temperature rise to the furnace temperature and then are returned to the atmosphere, eventually cooling to their initial condition. Considering the approach to and exit from the furnace, it is plain that equal quantities of substance rise on the one hand and fall on the other through equal ranges of temperature. This suggests the recovery of all the waste heat of the flue gases by regenerative air preheaters. Ideally, these should be contraflow, with such surfaces and velocities that all the heat of the burned gases is transferred to the incoming air—and fuel also.

Next, considering the process of combustion, it may be regarded as a simple liberation of heat which occurs when the fuel and air are brought into contact at a high temperature. Suppose the fuel to be insulated from the air during preheating until the furnace temperature is reached, when combustion is permitted. Suppose the boiler to be so large that it will absorb the heat of combustion immediately without allowing any appreciable difference of temperature, the working substance being, in the ideal case, at the furnace temperature. This amounts to an isothermal transfer of heat and completes a reversible cycle in the furnace, at least from a thermodynamic point of view. The chemistry of combustion is another question. Still retaining the purely thermodynamic viewpoint, the furnace temperature is ideally arbitrary.

Furthermore, if the boiler is operated at a lower temperature than the furnace, the consequent loss of availability, according to the Carnot efficiency, must be charged against the boiler or its working substance and not against the furnace, since all the heat of combustion would still be transferred to the working substance. On the supposition of a perfect transfer of all the heat of the flue gases to the entering air and fuel, there would be no thermodynamic loss in the furnace, and if, in addition, an isothermal transfer of the heat of combustion to the boiler could occur, then the boiler could be included in the statement.

The Engine. Rankine Cycle not Ideal

Turning now to the working substance in the engine, the steam is the first consideration. It is not necessary to discuss the Rankine cycle for steam. Instead of the adiabatic compression of the Carnot cycle an increase of pressure at constant volume is used, a process which is not reversible. The thermodynamic efficiency has been calculated from the steam tables and plotted in Fig. 1 for dry saturated steam and for various initial temperatures and pressures. A glance at the diagram shows that the higher the temperature, that is, the higher the ideal efficiency, the farther does the Rankine cycle fall short of it.

This is especially true in the case of superheat, even though it improves the actual efficiency. The ideal efficiency rises enormously faster than the change in Rankine efficiency with superheat. With saturated steam the conversion from liquid to steam in the boiler, the expansion in the turbine, and the condensation are all reversible processes, only the process of heating the liquid being irreversible. On the other hand, with superheated steam the absorption of heat is no longer isothermal, so that in this case two out of the four processes which go to make up the cycle are irreversible. Hence it is reasonable that the latter cycle should fall farther below the ideal. Moreover it follows that for any particular temperature the less the superheat the higher will be the efficiency. In fact, for a particular temperature the efficiency is far the best if the pressure is high enough for the steam to be saturated.

The Extraction Cycle

The question now arises as to what cycle can be used in order to cause the steam to turn over the heat in accordance with the best theoretical standards. Obviously, the superheated-steam cycle is far from ideal. In fact, it is hard to justify the use of superheat from a purely theoretical viewpoint, although its application is thoroughly justified by a variety of practical reasons which will be discussed eventually. The Rankine cycle with saturated steam has only one process, the feed heating, which is not reversible. The idea of a regenerative process consists in many small exchanges of heat occurring at successively different temperatures in infinitesimal steps. Suppose the steam-extraction process be pushed to such a limit. It has been called a regenerative process, and this is true.

Suppose steam is extracted from every stage of the turbine and that the number of stages is indefinitely increased. If at each stage just enough steam is extracted to heat the feed the infinitesimal temperature difference, each bit of steam so extracted has gone through a cycle reversible except for the infinitely small temperature drops during the feed heating, and these infinitesimal temperature drops occur in an unlimited number of small steps as in any regenerative process. The boiler temperature can thus be reached within

an infinitely small amount. In other words, the extraction cycle as a whole is entirely reversible in the limit.

In order to understand clearly the truth of this statement, the reversed cycle is traced as follows: Starting with a hot liquid, it is caused by a very small cooling to evaporate a part of itself isothermally at a reduced pressure and that part is compressed adiabatically to the higher pressure and temperature in the boiler where it gives up its heat isothermally and condenses into the hot liquid. Further cooling will evaporate a further quantity at a still lower pressure, and so on. If done in a very large number of steps the process may be rendered as close as desired to truly reversible.

The steam-extraction cycle with saturated steam is thus, in the limit, a truly reversible process with the ideal efficiency of the Carnot cycle. Furthermore the demonstration has assumed only the pressure-temperature relation of a wet vapor. It is good not only for steam, but equally correct for saturated ammonia or saturated mercury. However, it does not apply to the case of a superheated vapor. This is an important fact to understand clearly. The equivalence of the Carnot and extraction cycles was demonstrated in the days of the steam engine before the common use of superheat, and as a result the literature is not clear that the inference is true only for wet vapors and not for superheat. Furthermore it is easy to demonstrate this equivalence analytically on the basis of certain assumed algebraic relations of properties. Such demonstrations, using algebraic relations which are easily shown to be inexact, have failed to command confidence in the conclusion that the extraction cycle really is equal in the limit to the Carnot cycle.

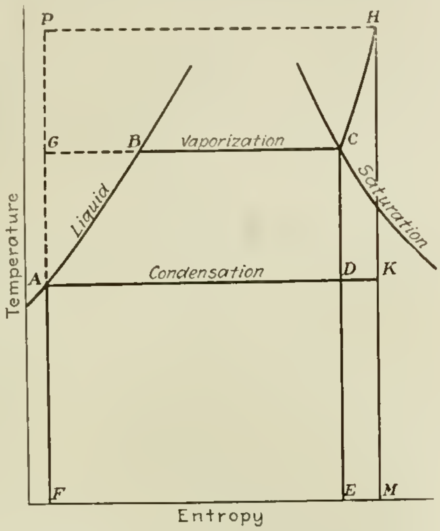

Fig. 2 Temperature-Entropy Diagram for Rankine Cycle with Superheating

This is about as far as abstract theory alone can go for the steam plant. The furnace and boiler have been imagined ideal by the use of regenerative air preheating with the flue gases, and the turbine has been imagined ideal by using saturated steam and heating the feed to boiler temperature by extraction. Thus the total margins for improvement are shown very clearly in Fig. 1, as explained before. The efficiency of the extraction cycle including superheat has been calculated according to the method outlined in the Appendix. It now becomes necessary to narrow the ideal still further by taking up the practical matters which determine the temperature limits and see what are the relative margins to gain among the various methods of increasing the efficiency. There are two principal questions: First, the temperature limits, and second, for established limits, how to approach as nearly as possible the ideal cycle.

The Upper Temperature Limit

The upper temperature limit is determined by the materials of construction rather than by the furnace or the working substance. Turbine materials maintain their strength, roughly speaking, up to 700 deg. fahr. Turbine steels are usually good up to 800 deg. fahr., but the gradient of decrease in strength per degree rise of temperature becomes so steep at higher temperatures that only very low stresses are allowable. Conservative practice therefore places 750 deg. fahr. as the limit at the present time. It has been made clear that, unless saturated steam is used, the efficiency of the process will fall far below the ideal. And with saturated steam these temperatures are above the critical and the pressure above 3000 lb. per sq. in. Both the excessive pressure and excessive moisture during expansion make it undesirable to use saturated steam at such temperatures. The curves for the extraction cycle and the Rankine cycle in Fig. 1 show very plainly the magnitude of this restriction due to the pressure of steam at saturation temperatures. The horizontal lines indicate Carnot efficiencies, and it should be noted that extraction efficiencies and Carnot, efficiencies for particular temperatures become equal at the saturation line.

The temperature-entropy diagram is useful for visualizing the differences in the processes. Fig. 2 shows the Rankine cycle *ABCD*. The heat put in is represented by the area *FABCDE* and the heat exhausted by the area *ADEF*. The Carnot cycle working between the same temperature limits has an efficiency which might be represented by certain areas constructed by drawing the lines *AG* and *GB*. For the same heat exhausted as in the Rankine cycle, the Carnot cycle would have to absorb heat *FGCE* and deliver work *AGCD*. It is plain, therefore, since the extraction cycle is equal in efficiency to the Carnot cycle, that it is represented by these areas, although only as areas, because the broken lines do not represent properties of the substance. Now with the superheated Rankine cycle the work area *DCHK* is added out of a heat addition of *ECHM*. The efficiency is raised because the added work area is a larger ratio of the added heat area than the original efficiency. But the work area of the Carnot cycle for the elevated temperature is represented by the area *APHK*, so that the small addition *DCHK* is a ridiculously unsatisfactory approach. Moreover the constant pressure line *BCH* is no longer isothermal. It is still possible to extract steam and heat the feedwater to the boiler temperature so that the efficiency may be made equal to and even slightly better than the Carnot efficiency for the saturation temperature *GBC*, but the feedwater cannot be heated to the upper temperature limit without encountering the excessive pressures already mentioned. Hence this large area between the saturation temperature and the upper temperature accounts for the failure of the superheat cycle to meet the requirements of an efficiency corresponding to its temperature.

The Advantage of High Pressure

It should now be clear why there is a theoretical advantage in the use of high pressures, even though the temperature after superheating is already at the limit fixed by the materials. In order to get the thermodynamic advantage of the highest temperature reached the steam must be generated at that temperature, a process which is practicable only for wet steam and provided that the required pressure is maintained. Thus it is clear that, due to the nature of a vapor, the pressure is quite as important as the temperature. The curves of Fig. 1 set forth the very material rise in theoretical efficiency with increase of pressure at various initial total temperatures, and it should be noted that the increase is still more rapid when steam extraction is employed. These curves have been carried to 1000 lb. per sq. in. absolute pressure. The manner of plotting on a logarithmic base renders the line so nearly straight that extrapolation is easy although it may not be warranted. Even at 1000 lb. per sq. in. the properties of steam are not known with precision. The pressure-temperature relation is, however, well defined and this shows that with saturated steam at 1000 lb. per sq. in. absolute pressure, using the extraction cycle, the efficiency, high as it is, only equals the Carnot efficiency for 542 deg. fahr. and the temperature at the critical pressure itself is only about 700 deg. fahr.

The Binary-Vapor Turbine

The foregoing all points to the necessity of a substance whose vapor pressure will not be excessive at the temperature to which the materials of construction may be submitted. And this is the great advantage of the mercury turbine. Fig. 3 presents a temperature-entropy diagram for one pound of steam with a similar diagram for ten pounds of mercury drawn at the higher temperatures. In a particular machine the relative amounts of steam and mercury would be slightly different, depending on the temperature of the condenser-boiler. The ten-to-one ratio is convenient for plotting. The low pressure of 45 lb. per sq. in. at 800 deg. fahr. is very satisfactory and the exhaust at one inch of mercury back pressure heats a steam boiler at 400 deg. fahr. and 250 lb. per sq. in. pressure, the steam from which may in turn be expanded to one inch of mercury back pressure. The entire working range of temperatures is from 800 deg. to 80 deg. fahr., and in each case wet vapors

are used. In each case, also, extraction may, imaginably at least, be employed, although the mercury has so little liquid heat, as a glance at Fig. 3 shows, that its Rankine cycle is considerably nearer to ideal than is the case with steam. However, considering the ideal case, a simple scaling from Fig. 1 shows a theoretical increase of economy of the process just described of 37 per cent, as compared with good modern turbine practice using steam at 350 lb. per sq. in. pressure and 700 deg. fahr. temperature, and a saving of 28.7 per cent as compared with the same turbine utilizing the extraction cycle to the limit.

The mercury turbine has thus given a practicable way to reach the upper temperature limit as fixed by the strength of materials. The aim in that direction is now being directed at the materials of construction, and this is entirely correct.

The Lower Temperature Limit

At the other end of the process, the condenser, the temperature limit is fixed by natural conditions. Cooling water sufficient to

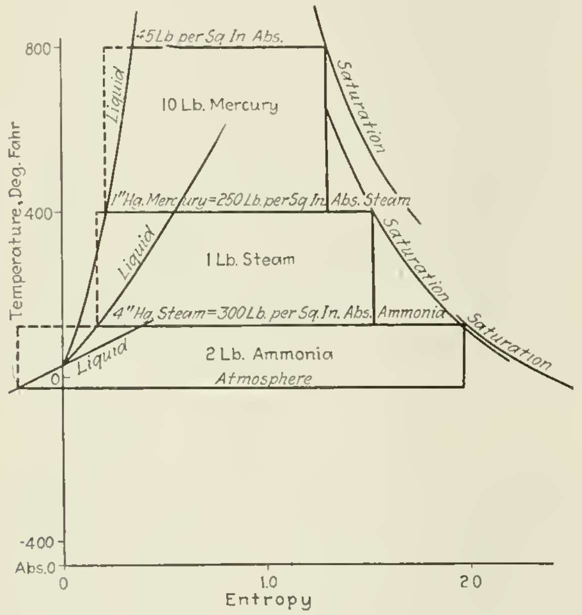

Fig. 3 Temperature-Entropy Diagram for a Combination of Mercury, Steam, and Ammonia

maintain a vacuum at 80 deg. fahr. is about as good as can usually be expected. However, it is the intention of this paper to look somewhat beyond immediate possibilities in a variety of directions. Fig. 3 also includes the liquid and saturation lines for ammonia, and if a turbine were supposed to be equipped with an ammonia condenser-boiler, then another turbine, an ammonia turbine, might as easily continue the process as the steam turbine continued the mercury process. If such a steam plant were located in the polar regions in winter so that the atmosphere could condense the ammonia at —25 deg. fahr., it would be possible to expand the ammonia to atmospheric pressure. Now if the feed is heated by extraction as in the case of the steam and mercury, the efficiency would be such as to effect a saving of 45 per cent over the case of a steam turbine working with the Rankine cycle at 350 lb. per sq. in. pressure and 700 deg. fahr. temperature.

It may also be noted here that sulphur dioxide could be used with less severe pressures than ammonia. This might be a matter for consideration if the process were adopted, and there is another reason than the efficiency of the process for the use of a refrigerating fluid for the last few stages. The capacity of the compound unit, being dependent on the last wheel of the steam turbine, could be very much increased if the steam expansion were stopped at a moderate vacuum and the remaining energy utilized in one of the suggested refrigerating fluids which have very much smaller specific volumes at the temperatures in question.

The Advantage of Steam Extraction

Having thus discussed what the theoretical efficiency is and how various practical limitations determine what is ideal in any particular case, the next matter to consider is the utilitarian question of the value of the various improvements already instituted. The idea is to take up step by step various limitations that lie between the application of the perfectly general theory and present steam-plant methods. The advantage of the mercury turbine has been pointed out. The theoretical advantage of steam extraction is shown in Fig. 1. The practical advantage depends on the number of heaters. Very roughly it may be said that, in comparison with no feed heating, the use of one heater will realize between a third and a half of the full theoretical gain, and also, very roughly, that each additional heater will realize an improvement about half as large as the last preceding heater added to the system. It remains to discuss the advantage of or reason for superheating, resuperheating, drying, the economizer, air preheating, and the use of auxiliary feedwater heaters.

The Advantages of Superheat

The advantage of superheat, as mentioned before, is almost entirely a matter of practical application due to the limitation of a high initial pressure. The desired temperature cannot be attained with wet steam without incurring too high an initial pressure. Hence the pressure is pushed as high as possible and the slight advantage illustrated in Fig. 2 is realized by superheating. The theoretical value is plotted in Fig. 1 in terms of total temperatures. Fortunately, the use of superheat is attended with a non-thermodynamic improvement in efficiency which is roughly of the same order of magnitude as the theoretical improvement. This is attributed to removal of moisture in the lower stages of the turbine. And still further the greater heat turnover per pound of steam results in an even greater reduction of water rate, which is advantageous in permitting a larger capacity rating of the machine, as will be discussed in another place.

In order to visualize these advantages it may be said, very roughly, that the theoretical gain in economy is about 1.5 per cent for 100 deg. fahr. superheat, while the non-thermodynamic gain is about as much more, making an overall reduction of heat rate in the neighborhood of 3 per cent per 100 deg. of superheat. The reduction in water rate is, on the other hand, of the order of 8 per cent per 100 deg. fahr. However, this must be clearly distinguished from an increase in the economy of operation of the plant. A reduction of water rate does not mean a corresponding reduction in the fuel rate because reductions in water rate usually entail a substantial increase in the heat per pound absorbed by the steam in the boiler.

Resuperheating

The desirability of resuperheating is due largely to the same reasons that apply in the case of initial superheat. But the newness of the process makes it less easy to say what the gain may be beyond the theoretical amount. Fig. 4 shows at a glance that the cycle has been improved, roughly, by nearly the same degree as in the case of initial superheat as compared with saturated steam. The process is accompanied by a further reduction of water rate, as explained before, which is greater than corresponds with the reduction in heat rate. In passing it may be noted that this resuperheating process is a sort of partial expansion under isothermal conditions. For instance, if the resuperheating should take place in each stage, this isothermal expansion might go on to exhaust pressure. There would be a slight additional gain in economy, but the efficiency of the process would not approach the efficiency of the Carnot cycle. The possibilities of practical application to any particular advantage are limited to about one or two steps of resuperheating.

Drying

Drying may be accomplished by the same process as resuperheating, namely, by the addition of heat; but if the addition of heat is only sufficient to dry the steam without superheating it, the gain will be slight and due largely to increased mechanical efficiency in the process of energy conversion. On the other hand, if the drying is done by moisture abstraction, the gain is very appreciable. The moisture removed should be used for feedwater heating, and the practical rise of efficiency due to drier steam in the turbine should be realized. Here again it is impossible to say how much improvement can be realized until the method is put into

practice. On the other hand, steam separators have been used for a long time, and the use of some form of separator in connection with extraction for feed heating would enable the removal of an especially wet sample of steam. In other words, instead of extracting a homogeneous sample, the extraction of all the moisture and only so much dry steam as might be required should enable one extraction drier used for feed heating to accomplish about as much gain in economy as, say, two extraction heaters of the surface-condenser type. This is a very rough statement and depends for its truth on the possibility of satisfactorily operating the drying process.

The Economizer

In all that has been said so far, there has appeared no place for an economizer. Indeed, as far as the theory goes, it appears to be anomalous. In considering the ideal furnace it was pointed out that flue-gas heat should be transferred to the entering air, and in considering the extraction cycle the logical source of feedwater heat was seen to be extracted steam. The economizer is intentionally aimed to extend the boiler process to a temperature below that

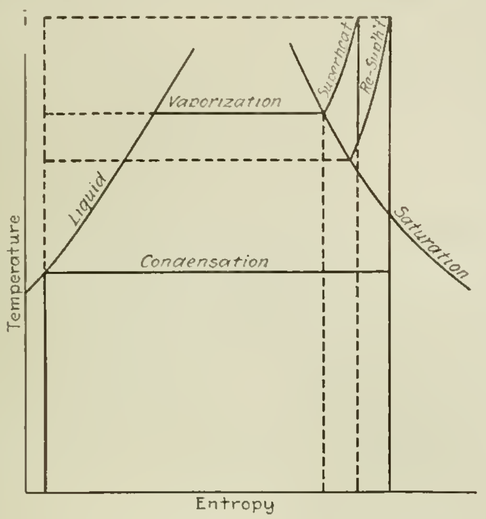

Fig. 4 Temperature-Entropy Diagram with Resuperheating

corresponding to its pressure; i.e., to destroy its isothermal nature. But in all these cases where a substantial practice has grown up there is always a good common-sense reason sufficient to justify it at the time. Whether the practice should continue or not is always an appropriate question. The discharge of hot flue gas was a material waste. To pump cold water into a hot boiler was bad. And the transfer of heat from hot gas to water was a practical process well known, since it was taking place in every boiler; hence the economizer.

To secure an exchange of heat between large quantities of air with reasonable temperature differences is not so easy. The design of such apparatus is progressing at the present time, however, and installations of this nature have been made. It is certainly a process theoretically of such distinct value as to warrant serious attempts to accomplish its practical use. On the other hand, the success of this process will not in itself displace the economizer. The economizer works at temperatures roughly between 300 and 600 deg. fahr., whereas grate manufacturers prefer the air to enter the furnace at a temperature less than 300 deg. fahr. or certainly not much more. This is another very real limitation on the realization of the ideal arrangement. The inability to utilize this flow of fluid for returning low-grade heat to the furnace means definitely a corresponding amount of waste. Here is a very good reason for pulverized fuel, if it will permit the use of very hot air going to the fire.

Air Preheating from the Economizer

There are several alternative methods of connecting up these channels for the return of low-grade heat to the system. In examining them it should be kept in mind that the idea is always to have the heat transfer occur with the least possible temperature difference. That is, the process should be as nearly truly regenerative as possible.

One suggestion that has been made with a view to transferring the heat of the exhaust gases to the incoming air is to fill the economizer with an auxiliary hot-water heating system and pipe this to hot-water radiators in the inlet-air system. Such an arrangement would avoid the bulkiness of air-to-air heaters. But it does not commend itself on account of its complexity, although the contraflow feature of a regenerative process might be utilized at each end. Moreover the water would have to be confined under a very considerable pressure in order to attain the necessary temperature. Such a system would, however, leave the feedwater free to absorb the heat of extracted steam, and perhaps a more suitable auxiliary liquid than water could be selected for the transfer of the heat of the flue gases to the air.

Air Preheating with Extracted Steam

The use of extracted steam for air preheating is another scheme. If the economizer is used at the same time, it will be observed that the recommended arrangements of the ideal process have been crossed. In detail, instead of recovering the low-grade heat by the two regenerative processes, flue gas to air and extracted steam to feedwater, the following processes have been substituted: Flue gas to feedwater and extracted steam to air. This is all right as far as it goes, but examination shows that the crisscross is not equivalent to the direct process. To make this plain it is noted that very roughly two pounds of air flow are required to one pound of water, whereas the specific heat of the air is only about one-quarter as much as that of the water. In the upshot, then, the air circulation can carry back only about half as much heat per degree rise as the water circulation. Moreover the limitation of grate temperature has been noted. It is thus evident that, even if all the air preheating should be done by extracted steam, it would still be desirable to extract more for feed heating.

Parallel Feed Heating

Still another arrangement occurs to the author. The economizer must receive reasonably cold water in order to work efficiently, whereas the extraction process is not pushed to its limit unless it heats the water to boiler temperature. Present arrangements send the feedwater from the heaters to the economizer, thus dividing the available temperature range between the two heating devices. A more efficient way than to divide the temperature rise would be to divide the circulation into two very roughly equal parts (supposing pulverized fuel and no limitation on the air-preheating temperature). One branch of the system would be sent to the economizer as it comes from the hotwell and should enable the cooling of the flue gases to a materially lower temperature than with feedwater already preheated. The other branch of the system should be arranged to receive extracted steam, including appropriate amounts from the high-pressure stages, since these temperatures no longer detract from the action of the economizer. Similar amounts of extracted steam would be used for preheating the air. Such a process in perfect adjustment would approach the ideal process.

The House Turbine

It is now time to discuss the use of a house turbine for feedwater heating. Very simply, if the house turbine has the same efficiency as the main units it is exactly equivalent to single-stage extraction. A house turbine is rarely as efficient as the main units, and generally means a less economical heat rate than extraction from the main units. On the other hand, it has certain advantages in the way of flexible adjustment that cause its use as a so-called "heat-balancer" element. By shifting the load on the house turbine the temperature of the feedwater may be regulated. It would be preferable to control the quantities extracted from the main units.

Steam Auxiliaries for Feed Heating

If steam auxiliaries are used for other reasons, the exhaust heat from these may be used for feedwater heating. It is interesting to read descriptions of this common practice which seem to reflect an opinion that it is desirable to create a number of losses in order to have losses to recover. Steam auxiliaries are usually very inefficient as compared with the main unit and therefore not to be compared with motor drive. In consequence the use of such heat is a waste as compared with extraction from the main unit. Furthermore

this heat is rarely added regeneratively but is dumped in at once, so that it reduces the ability to extract other steam more than in proportion to its own value.

The wisdom of having certain auxiliary drives duplicated by steam stand-bys in the interest of station reliability is not disputed at all. But it is maintained that the deliberate layout of a plant to heat the feedwater with such steam on the supposition that it is not lost is wrong because such a layout prevents the use of another arrangement which is more efficient. The heat returned to the system is not lost in itself, but for a given quantity of heat recirculated the auxiliaries can turn less into useful work than the main units. In other words, inefficient auxiliaries should not be placed in a station in order to provide feed heat which may be got from the more efficient main units.

Other Sources of Low-Grade Heat

There are also several other sources of low-grade heat about the station which may be used for feed-heating purposes. Among these may be listed the following possibilities: The exhaust from the turbine high-pressure packings; the heat of the steam air ejectors; the heat of the bearings as recovered from the oil coolers; the generator losses as recovered in the generator cooling-air circulation. In such cases it is perfectly plain that the loss should not be created in order to get the heat. But having the heat it is allowable to use it, especially if it does not hinder the use of other heat. In every case the process should be as nearly regenerative as possible, and the final test of usefulness is the effect on the heat rate of the station as a whole when compared with that of some other arrangement.

The Final Criterion

The importance of considering the station heat rate as a whole is not always appreciated. As soon as the boiler plant and the turbine plant are connected by the regenerative processes the whole station becomes a single thermodynamic unit, and it is no longer possible to judge its economy by considering separately the boiler and the turbine. For example, the economizer may be made extremely efficient at the expense of all feed heating by extraction. Or the reverse may happen so that there is excessive waste in the flue gases. The only safe rule is to look at the heat rate of the whole plant. Furthermore, in accepting such a criterion the electrical apparatus must not be lost sight of, nor the fixed charges. No one would consider for a moment doubling the investment to obtain a one per cent increase in economy, and it is unwisdom of the same sort that focuses attention on any one element of the plant to the exclusion of its effect on the whole.

Capacity Rating

In conclusion, it seems necessary to consider the effect of the various improvements on the capacity of a unit. This relation has been noted repeatedly in passing, and it is a fortunate circumstance that improvements in efficiency usually result in a greater power output from a given amount of working substance and thus tend to increase the rated capacity of a machine. In the case of a particular turbine of large size, the rating depends on the volume of steam passing the last wheel so that reductions of water rate, especially water rate at the last wheel, cause corresponding increases in the rated capacity of the turbine. The reduction of water rate with superheat has been mentioned. A similar reduction occurs with increased pressure. The effect of steam extraction is obviously to reduce the water rate at the last wheel. Recent advances in the rating of single turbine units have brought the importance of this subject to the front, and it seems necessary to point out here the great increase in capacity which theory alone provides in the case of machines using the improvements which have been discussed.

Fig. 5 is a chart of reciprocal water rates or theoretical capacities in kilowatt-hours per pound of steam at the condenser. Curves have been plotted for the Rankine cycle with superheat and for the extraction cycle. Although the specific volume at the exhaust does not vary greatly, very fine lines have been added to show its theoretical value. A comparison with Fig. 1 shows at a glance how much more rapidly the capacity rises than the efficiency. For instance from 130 lb. per sq. in. absolute and saturated steam with the Rankine cycle to 750 lb. per sq. in. and 750 deg. fahr. temperature with the extraction cycle, the capacity is just doubled while the economy is improved one-third. In this example the theoretical specific volume at the exhaust is the same in each case.

In the case of increased superheat at a fixed pressure the capacity rating of the machine increases less rapidly than the capacity per pound on account of the greater exhaust volume. On the other hand, with increased pressure at a constant superheat the capacity rating increases more rapidly than the capacity per pound because of the reduced exhaust volume. Generally speaking, increases of superheat have been accompanied by increases of pressure, so that exhaust specific volumes have been changed very little. It should therefore be plain that the continual increases of turbine rating which have occurred in the past decade without recourse to double-flow or multi-flow construction have been largely due to true improvements in the thermodynamic processes. How much farther such improvements can be successfully carried is still to be seen.

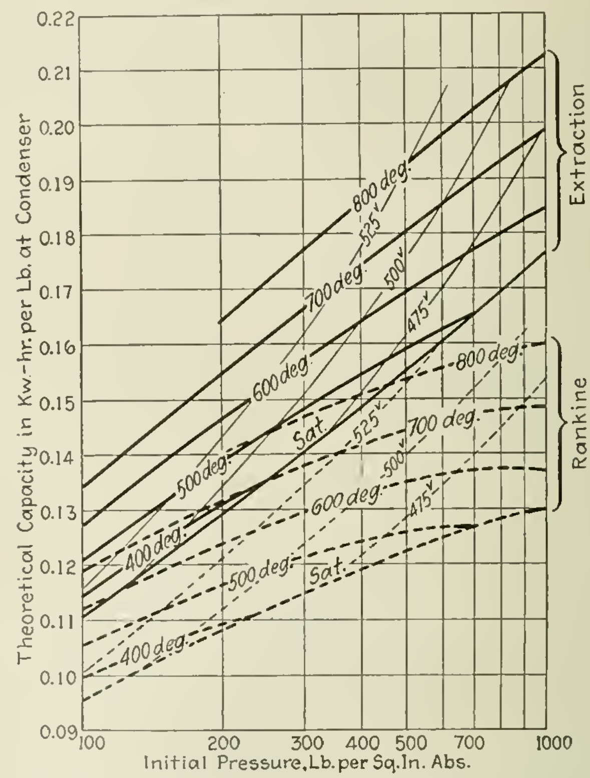

Fig. 5 Theoretical Capacities of Steam Cycles

(Curves are for various initial total temperatures in deg. fahr. as indicated. Back pressure 1 in. Hg. Fine lines show exhaust specific volumes in cu. ft. per lb. Based on Goodenough, 1917.)

Appendix

The formulas for calculating the theoretical value of steam extraction as shown in Fig. 1 and Fig. 5 are given herewith. One pound of steam is supposed to go to the condenser. At any pressure during expansion the quantity of working steam is $(1 + w)$ lb. At this pressure the corresponding total heat is H and liquid heat is h. The subscript 1 indicates the initial pressure and 2 the exhaust pressure. The formulas are expressed in terms of liquid heat at any pressure. e is the base of the Napierian system of logarithms.

The heat balance for any particular infinitesimal heater gives the relation:

$$dw(H - h) = (1 + w)dh$$

Integrating, the amount of working substance is:

$$1 + w = e^{\left[\int_{h_2}^{h} \frac{dh}{H - h}\right]}$$

The energy E added to the Rankine cycle per pound of steam in the condenser, which is also the extra amount put in by the boiler per pound of steam in the condenser, is given by integrating the following expression for the work done by the steam going to any particular infinitesimal heater.

$$dE = (H_1 - H)\, dw = \frac{H_1 - H}{H - h}\,(1 + w)\, dh$$

$$E = \int_{h_2}^{h_1} \frac{H_1 - H}{H - h}\,(1 + w)\, dh$$

These formulas are used by tabulating or plotting the quantities as functions of the liquid heat. The integration is then performed graphically and the efficiencies and capacities are easily calculated.

Factors in the Spontaneous Combustion of Coal

By O. P. Hood,[1] Washington, D. C.

This paper discusses the phenomena incidental to the self-heating of coal when subjected to change in environment and analyzes the effect of the self-heating on the piling of coal. The author states the fundamentals to be observed in storing coal with the minimum danger of spontaneous combustion.

IN ORDER that the engineer may intelligently consider the phenomena of spontaneous combustion of coal, he must receive from both chemist and physicist some general ideas about the coal substance, about the character of coal surface, about the atmosphere in which it may be immersed, and about slow combustion. The coal substance is extremely complex in its chemical relations. Carbon, hydrogen, and oxygen products of fairly definite chemical combination have been brought together in ages past under conditions where rearrangement, exchange, and elimination of elements have progressed at first rapidly and then at rates infinitely slow, until a practical equilibrium has been attained in the substances we find in the ground as coal. Change the surrounding condition, however, and recombinations may begin again. These may be very slow at normal temperatures, but at elevated temperatures they are rapid, and we call the process combustion.

A particle of coal within the mine has for its immediate neighbor a similar particle with which it has exchanged molecules, perhaps, and suffered common losses, until further reaction has practically stopped. This particle, removed from the mine, is surrounded by air from which it had been shielded for ages, and its moisture, temperature, and pressure environment become different.

We should expect considerable variation in coal, since the original vegetation from which it came varied in composition and was laid down in varying proportions, and its environment through the long ages has differed from place to place. Therefore the final equilibrium attained must be different in each case, and we have our anthracite, our bituminous, and our lignite coals.

Atmosphere Reacts with Freshly Broken Coal

When mined it is the freshly broken coal surface that experiences the greatest change and which finds its equilibrium most seriously upset. The boundary between the coal and the air looks smooth, perhaps, but when we apply the conceptions of the chemist the surface must be a jungle in which gas molecules become entangled, condensing on the surface in great numbers. The surrounding atmosphere may carry not only nitrogen and the active oxygen, but also vapor of water and other gases. The temperature will also change. Powdered coal sealed in a bottle with air gradually takes the oxygen of the air into combination, reducing the pressure in the container. Some CO_2 is formed, but not enough to account for all the oxygen. There is slow combustion, as we know it, and other reactions less definite and less stable. Various loosely held oxygen relationships are established on and in the immediate surface. Some coals will take up as much as 6 per cent in weight in this process. Entertaining this point of view it is not surprising, therefore, that there is an attempt to reëstablish chemical equilibrium at the fresh surfaces, and that in these recombinations heat may be given off. Small amounts of heat may be generated in other ways. With the coal substance are minerals, and these also find themselves in strange environment and proceed to change. Heat may be generated from other than chemical rearrangements. If very fine silica sand be slightly moistened with water, heat is generated. There is no chemical change, but the deposition of moisture on the great extent of curved surface in some way generates a small amount of heat.

To sum up, we can expect a fresh broken surface of coal to be chemically active in some way, seeking to establish equilibrum under new conditions. The amount of the activity will vary with the particular coal, the amount of surface, and the environment. It will be rapid at first, and finally be so slow as to pass out of our interest. These changes may develop heat; they may add to the weight, and may finally reduce the weight by inducing combustion. The principal source of heat is the coal substance itself, whatever may be credited to the usually small percentages of associated minerals. Being a surface phenomena it will become noticeable only when the surface is large.

In Changing Environment, Coal is Self-Heating

The rate of these chemical readjustments is greatly increased with increase of temperature. Chemists say that, generally speaking, the rate of chemical combination doubles for each 10-deg. rise in temperature. Coal at ground temperature, when removed, is apt to be sent into warmer surroundings. If the surroundings are such that the heat generated cannot escape, the process becomes self-aggravating, with an increasing acceleration, so that very small heat quantities following this law in time become large. As the temperature rises new reactions also become possible, involving other constituents of the coal substance. J. D. Davis, of the Bureau of Mines, has devised an adiabatic calorimeter which provides an environment for coal which follows exactly the momentary temperature of the coal. Fine coal through which oxygen of the same temperature is made to flow rises gradually in temperature from 150 deg. fahr. until a critical point is reached, when the temperature rise is greatly accelerated. There is an elbow in the plotted temperature curve. This critical point is different for different coals, but is around 185 deg. fahr. In this device coal can be caught in the act of self-heating, rates can be plotted, and comparisons of behavior made.

When a coal surface is elevated in temperature above that of its surroundings it will lose heat by conduction, radiation, and convection. The body of the piece will itself be heated by conduction. Obviously, if the mass is large compared with the surface, as in coarse coal, the rise in temperature of the mass will be small as compared to the condition of fine coal where the total surface is large compared to the mass. Radiation at these small temperature differences is a small factor in the case. Convection is believed to play a considerable part in the problem. Air, vapor, and gas currents normally move across a coal surface, removing heat and carrying it elsewhere, and a temperature equilibrium is soon established at a slight elevation above that of the surroundings. In a pile of coal these movements are usually present. From 25 to 45 per cent of the volume of a pile is void spaces between coal particles, through which a comparatively free movement of air is possible when the pieces of coal are of appreciable size. A light wind pressure would change the air in the pile many times daily. If, however, the particles are quite small although the void percentage may be the same, the resistance to flow of air would be great, and much less exchange of air and heat removal would follow. The ordinary daily barometric and temperature changes produce a breathing in such a pile that would exchange air, and if any portion becomes perceptibly warmer a chimney effect is also possible. These vagrant air movements within a pile are beyond computation, prediction, or practical measurement, but their existence determines largely whether we shall have a dangerous heating in a pile of coal or not. If the movement of air be reduced to zero, the oxygen is soon completely engaged with new relations and the very small rise in temperature is stopped. If there is a considerable movement of air, any heat generated is carried away. There is therefore some rate of air movement too slow to carry heat away but sufficient to keep up the supply of oxygen and produce the maximum heating effect. The problem of coal storage is to prevent this condition, or if it exists, to discover it before a critical temperature is reached, and rearrange and cool the particles at the local point of heating.

Coal Piles Present Peculiar Ventilation Problem

A conical pile of run-of-mine coal made by dumping from one point will have a central core of small-sized particles. Air exchange

(Continued on page 694)

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Contributed by the Fuels Division for presentation at the Annual Meeting, New York, December 3 to 6, 1923, of The American Society of Mechanical Engineers. All papers are subject to revision.

The Mechanical Engineer in the Management of Woodworking Industries

By W. L. Churchill,[1] New York, N. Y.

The vital need of the mechanical engineer in the management of woodworking industries is depicted in this paper. His knowledge is called for in almost every phase of the industry—from elimination of waste in felling and transporting the timber to the sale of the finished products. The economical arrangement of machinery, the correct handling and caring for lumber, the conservation of man power, the conversion of waste into fuel and power, the design of the product, and many other problems are all within his province. The author believes that the introduction of the properly qualified engineer into woodworking management will place the whole industry upon a more profitable basis, as well as open up a large field of usefulness for the mechanical engineer.

THERE are in the United States alone some 15,000 woodworking firms with $50,000 and over invested in each; there are about 18,000 sawmills with similiar capitalization, and more than 500 logging companies of substantial size. Here are more than 33,000 concerns that need the help and guidance of mechanical engineering principles in their management. A large proportion need and would profit substantially by having mechanical engineers as permanent members of their management staff, and not a few would be wise to secure high-grade mechanical engineers to manage them.

The mechanical engineer in the management of woodworking industries is almost unknown. So rarely is he found in this connection that he usually occasions surprise and wonder as to how he happened to be there and why the responsible power selected him instead of a "practical woodworker." And yet there is no major industry that is more in need of the mechanical engineer in its management functions than the broad class of enterprises coming under the head of woodworking.

This fact when recognized by the mechanical engineering schools and profession will open up a large field of usefulness for the mechanical engineer heretofore comparatively neglected. It will also tend to correct many of the inefficiencies now existing in woodworking operations and place the industry as a whole upon a more profitable basis.

Not only does this field open up a large number of opportunities for the properly qualified engineer, but his introduction into the industry will lift its present low average of earnings to a much more satisfactory level.

A tremendous amount of progress has been made in the development of woodworking machinery, so that today they are marvels of mechanical efficiency and a credit to the mechanical engineering profession for their design and development. This development, however, has been accomplished almost altogether by manufacturers' catering to the woodworking industries, rather than from within these industries. Likewise there have been developed equipment for handling and transporting logs, timber, lumber, veneer, and their products and by-products, as well as for drying, treating, machining, and finishing, that are in every way a credit to the mechanical engineering profession, but in very few instances have these developments been obtained without the aid of other industries or firms furnishing the mechanical engineering talent necessary to place them on a practical and efficient basis.

Waste of Man Power

A typical instance of the result of failure to recognize the importance of having mechanical engineering knowledge in the management is the case of a certain large lumber and lumber-products corporation. The required output of the sawmills was beyond the ability of men to remove and keep pace with sawyers.

A long sorting table was built to catch the lumber as it left the saws and carry it past rows of men stationed to remove it to lumber wagons. Each man removed only a single width and grade of lumber, resulting in a tremendous lot of idle time per man, since the mill cut the timbers as delivered to them in cars of mixed widths. Arranging the delivery to the resaws of timber in separate lots of the same widths reduced the sorters from 26 men to 6 and eliminated the need of some 600 ft. of sorting table.

The engineers called in to design and construct the sorting table had done a good job from the mechanical standpoint, but it required another engineer, trained in the managerial aspects of engineering, to detect the perfectly obvious need of serving the sorting table more intelligently. None of the corps of practical woodworkers on the management staff had observed this opportunity for improving management and reducing costs.

This is by no means an isolated or exceptional instance. It is practically impossible for an engineer to enter any woodworking plant and not observe numerous opportunities for major improvements in methods of production, in arrangement of equipment, in utilization of materials, and even in design of products, all offering additional earnings of substantial proportions

Opportunities for Mechanical Engineers

Wood-cutting machinery is so rapid in its operation that the problem of supplying machines with enough work to utilize their capacity, and the further problems of removing the product, often offer opportunities for the mechanical engineer that enable him to greatly increase plant output and plant profits with comparatively little investment in additional equipment. Few plants devoted to woodworking have their machinery arranged for the most economical production; this problem is peculiarly that of the mechanical engineer and it is not unusual for him to find a large surplus of machinery and of floor space available when he goes into the woodworking plant to improve profits.

In lumber handling and drying there are many opportunities for engineering skill to increase the ultimate yield of merchantable product and earnings as well as to reduce wastes.

Studies of the effects of different methods of piling lumber have disclosed that in this simple operation much material is spoiled or reduced in value because of lack of scientific knowledge of the correct way to care for lumber after it is produced. To the mechanical engineer confronted with the task of handling and caring for lumber, these facts appear perfectly obvious.

In the process of drying lumber the engineer has demonstrated that his profession can be of great value to the woodworking industry. But here again he finds himself on the outside of the industry and obliged to demonstrate the practicability of his ideas at his own expense, and then to sell them to some one willing to prove them out with such modifications as he may see fit to apply. There has been appreciable progress in this field, but the opportunity for further development is one to appeal to the ability of the best of engineers. He should be in a position to carry on this development as part of a management function.

The proper artificial drying of lumber affects every subsequent operation. It has a large bearing on the proper service to customers, cost of production, and even on financing policies. Manufacturers of piano cases, vehicles, and high-class furniture were accustomed in the past to insist upon lumber receiving two years or more of air seasoning before use. Today a large and growing proportion of these manufacturers are artificially seasoning their lumber in two weeks or less, as a result of developments in drying methods largely the outgrowth of engineering research.

The difference between a two years' supply or a few weeks' supply of expensive lumber with the attendant costs for storage space, insurance, spoilage, and loss means a tremendous difference in capital tied up and in the amount of business that can be done on the capital invested. This is only one of the many services that mechanical engineering has furnished to the woodworking industries.

In regard to the allied industry of logging, one engineer who has

[1] Industrial Engineering Service. Mem. A.S.M.E.

Contributed by the Management Division for presentation at the Annual Meeting, New York, December 3 to 6, 1923, of The American Society of Mechanical Engineers. All papers are subject to revision.

specialized for a number of years in consulting service to lumbermen states that anywhere from 5 to 15 per cent of the available footage of logs is left behind by the wasteful methods of felling and transporting. Although not strictly within the class of woodworking industries these operations are often a part of the larger woodworking enterprises, and the opportunities for the mechanical engineer in their management are not confined to the conservation of the selected logs. The labor of logging is today a challenge to our mechanical engineers for practical mechanical means for reducing the amount of strenuous and dangerous effort now expended for all of the logging operations.

We need mechanical devices and aids for clearing the roads and pathways to the trees to be felled, and for haulage, as well as mechanical means for cutting down and turning the trees into suitable logs for transportation.

Some progress has been and is being made in these directions. If mechanical engineers were interested in the management of the lumber companies this progress would be much more rapid than is now possible, where the engineer is required to work out his ideas independently and then offer his completed device for sale, which is now practically his only means of approaching these problems.

Power Generation

Another phase of woodworking operations that belongs particularly to the mechanical engineer is the question of power generation and distribution. A large proportion of woodworking plants depend chiefly, and many of them entirely, upon their wastes for fuel, with which they generate their own steam for power, heating, and drying purposes. Many purchase no fuel whatever, and not a few even operate refuse burners to dispose of the wastes that are not needed for fuel.

Having much waste to dispose of, it is not surprising that power plants of woodworking industries are notoriously inefficient, and that power distribution is commonly considered from the standpoint of the easiest way to install equipment, rather than how to economize and conserve the power to be used. In some plants, boilers and engines of abnormal excess capacity are deliberately installed because of a supposed excess of available free fuel in the form of waste. It is common to see steam exhausting to atmosphere and the safety valve blowing for hours at a time, all in efforts to consume wastes, using the power and heat generated only as a by-product.

This condition in turn creates carelessness as to insulation of steam lines, dry kilns, etc., that the mechanical engineer interested in the management of these plants must find contrary to his ideas of good management and to present an opportunity to effect economies. However, here he is confronted with the practical woodworkers' logic of "what is the use of economizing on power when you only have that much more waste to dispose of through other means than by burning under boilers?"

Of two woodworking plants operated by the same manufacturer, one operated without purchasing fuel, while the other required the purchase of coal. The superintendent of the latter was criticized for failure to operate his power plant as efficiently as that of the first mill. An investigation of the two plants by a mechanical engineer revealed that the plant purchasing fuel was really the more efficient, for the reason that the other plant was making excessive waste of high-grade lumber. This waste, used as fuel, was the equivalent of coal at $150 per ton.

Waste

This leads us to what is probably the one factor in woodworking operations that offers the mechanical engineer his greatest opportunity to create large additional profits for the woodworking industries and at the same time to conserve our remaining forests, or at least retard their present rapid rate of extermination. This factor is the factor of waste.

In woodworking the wastes of the major materials used are appalling. They take place at practically every step of the process, from cutting the trees in the forest to final polishing of finished products. These wastes are in large measure inexcusable, and are due to lack of intelligent efforts to prevent them, or to create by-products from them. This is a field where the mechanical engineer should shine preëminently, but he will not find it easy to overcome the inertia of fixed habit in the industry and the general complacency with which these wastes are viewed by those who make them.

Most woodworking concerns will admit that the material they waste, destroy, or throw away, if converted into merchantable products or if reduced in quantity, would add appreciably to their earnings. Many of them will admit that it would make the difference between profit and loss if these wastes could be only partially overcome, yet few will adopt suggestions or experiment intelligently with ideas offered to this end. The reason is that it needs men of engineering instincts and training as managers or supported by the management of these enterprises to attack these problems scientifically to enable their full benefits to be realized.

It is rare to find the engineering type in woodworking enterprises. Therefore progress in this direction is lamentably slow and will so continue until the mechanical engineer is admitted into the industry in its management functions.

In the manufacture and preparation of lumber and veneer for marketing, the planning for maximum values to be obtained from the logs handled can increase the earnings beyond any imagined losses due to retarded production caused by exercising care to insure obtaining greatest possible values from these logs.

The practical woodworker is prone to pride himself on quantities produced and has little ability to visualize the quantities into money. When it is understood that in lumber operations variations in widths and lengths of material obtained from a log create variations of values sometimes as great as 6 to 1 for the same quantity of production, it will readily be understood why the engineering attitude in management of these enterprises is essential to their best returns. The engineer's first concern is for relative values rather than relative quantities. By consideration of this factor alone nonprofitable plants have been quickly placed upon a profit-making basis by engineers.

Operations subsequent to lumber preparation usually call for specific dimensions of materials, and it is in the reducing of lumber and veneers from their log-run dimensions to those specified that the largest amount of wastes are produced.

Figures compiled from a group of more than 50 manufacturers of furniture and furniture parts, veneer and veneer products, disclose that less than two-thirds of all the lumber, logs, and veneers purchased by them leave their plants in the form of merchantable products. The remainder, equal to 50 per cent of their finished products, is burnt up or wasted.

Even crediting at fuel value such wastes as should probably be used for generating steam for heat and power, there is still a tremendous waste of perfectly fine but small-dimensioned stock that can be put to more useful and profitable purposes.

Even most of the lumber ends and edgings of sawmills are suitable for some marketable product, and such as are not, along with shavings, sawdust, etc., should be convertible into pulp stock, or pulp products, chemicals or other materials that can use such refuse in the mass as a base. With the mechanical engineer in the management functions of woodworking industries we should quickly be able to as thoroughly utilize our woodworking wastes as the meat-packing industry, where as the saying goes, everything is saved except the animal's squeal.

There is nothing visionary or even difficult in such a realization, and it will add tremendously to the profit-making possibilities of woodworking enterprises that are now earning altogether too little. It can also reduce in large measure the amount of timber we need to cut for our normal requirements, and conserve our timber resources.

Design of Product

Although we have touched briefly on the larger problems of management in which the mechanical engineer can be of most benefit to the woodworking industries, these are not his only opportunities to aid them.

In his generally accepted field of mechanical design and detail he can be of very great benefit especially in manufacturing of furniture and other products retailed to the general public. The structural design of a large proportion of these products today strikes the engineer as being anything but mechanically correct, and many show utter lack of the conception of sound mechanical design. Apparently the principles of bracing, of the truss, and the arch, and proper conservation of materials are almost unknown in the products of wood working establishments. As proof of this it is only

necessary to refer to a series of nationally distributed advertisements now being presented that shows how the simple task of crating furniture and other products can by proper mechanical design of the crates save lumber, freight, labor, and prevent damage to the crated products that together pile up a sizable economy, and justify the engineer for even the simple task of designing wooden packing cases.

It may be offered in objection, that many of our wood products are designed for attractiveness and style, in fact by artists rather than engineers. This does not prevent the use of engineering principles applying to the strength and durability, as these can be effected without sacrifice of symmetry and beauty.

In fact, if engineering design were the first essential, many of our pieces of furniture and other articles of wood construction would be much more attractive than is now the case. Strength and durability call for symmetrical proportions and there is no reason why the artist cannot embellish and decorate articles of correct mechanical design as easily as the architect enhances the appearance of bridges and other structures calling for correct mechanical design first.

Sales

Even the sales problems of many of our manufacturers of wood products would obtain a more satisfactory solution were the mechanical engineer a part of the management function. Too little consideration is given to the effect of sales policies upon the costs of production and their limitations of plant output and ultimate profits.

The engineer is trained to analyze all causes and effects and to forecast and plan for definite results, whether in design and construction of a machine or an organization. The same principles of research and application of established facts pertain to the intangible machine as to the tangible one.

The Engineer and Management

To the mechanical engineer belongs the credit of reducing management to a definite science. The mechanical engineering schools are including in their courses the facts and elements of management science as rapidly as they become defined. Their special application to woodworking industries has not been presented as strongly as the needs of these industries warrant, and this neglect has prevented the engineer from realizing his opportunity just as much as it has prevented the woodworking industries from receiving the benefit of his engineering training.

This condition should be changed. The woodworking industries need help. As a class they are in a deplorable condition. Profits are meager and their products are being supplanted with metal, cement, fiber compounds, paper and other substitutes, in many cases where wood is unquestionably the best material for the purpose. Costs are excessive, quality is getting poorer yearly, and sources of supply of primary materials are being rapidly depleted.

Some of these changes are inevitable and have come to stay. There is, however, much to be done for the industry that will secure for it just recognition of its place, put it on a more stable profitable basis, and eliminate its destructive features. The mechanical engineer is needed in the management of these enterprises in order that their problems may be intelligently solved.

Here is a field that is comparatively unknown to the mechanical engineer, and that hardly knows him. Our problem is to bring them together in mutual understanding of each other. When this is done our rapidly increasing supply of mechanical engineers will be quickly absorbed into a field where they will make as notable improvement as already stands to their credit in lines of metal manufacture and other industries.

When the woodworking enterprises are brought to realize where the mechanical engineer belongs in their industries they will change their present demand for practical woodworkers to a demand for practical profit makers in their management.

The general economic effects of the introduction of mechanical engineering into these industries would be such as to warrant it having a major place in the activities of our society and in those of the Federated American Engineering Societies.

Here is a practically unoccupied country with room for several thousand mechanical engineers and sorely needing them. Just as in any other new country that an engineer might adopt for his residence he will need to adjust his habits, his ideas and even his language to that of the established inhabitants. Where he has been accustomed to working limits of thousandths of inches he here finds one-eighth inch a close measurement.

Here is an industry that is full of tremendous energy and high-speed operations that are in vivid contrast to the slower painstaking motions of metal working, and the engineer who adopts woodworking as his chosen field finds in it a class of men who are quick thinkers, direct actionists, and delightful companions. There is no field where he can hope to be more happily situated, and none where he is more vitally needed, than in the management of woodworking industries.

Spontaneous Combustion of Coal

(Continued from page 691)

through this will be extremely slow. With such handling coal sizes are classified, and will grade from the finest in the center and top to the coarsest on the bottom and lower flanks where there is ample ventilation. Between these extremes, part way up the flanks and below the surface, there is likely to be a most favorable condition for spontaneous combustion, where the coal is fine enough to give a large surface of fresh broken coal and the ventilation too low to carry away the heat and yet sufficient to keep up the oxygen supply. The hazard is thus greatly increased by allowing this classifying action in building the pile.

The part that moisture plays in this problem is of interest. A distinction should be made between the moisture considered by the chemist and moisture as known to the operating man. In the one case water vapor may play a part in the chemical drama, perhaps being necessary to some reactions, and enter into the problem of swelling mineral crystals that break up the coal into finer sizes. To the operating man moisture means something he can see, a heavy rain on a car of fine coal, or perhaps drenching a pile of coal to cool it off. The latter effects are believed to be largely physical and mechanical. Fine coal will hold 15 or 20 per cent of free water, and such coal is practically impervious to air currents. The locomotive fireman wets his fine coal in order that the draft shall not at once blow through the coal. A dry pile which may be sufficiently ventilated may be partially sealed if wet, and reduce the ventilation to a dangerous point. The conclusion often reached is that wet coal fires easier than dry coal, but the conclusion should be that the ventilation was so restricted by an impervious blanket as to furnish favorable conditions for the accumulation of heat. Putting water on a hot part of a pile only seems to furnish a good carrier of heat to other parts of the pile, and to disturb ventilation, unless large quantities are used and the pile drenched. Even here it is possible to have the under part of a large coal piece glowing while a heavy stream of water is shed from the top as from the roof of a house.

Practical Coal Storage

The application of these thoughts to practical coal storage lead to the following conclusions, which seem to agree with best current practice.

There must be no heat added to the coal from outside sources, such as hot walls, steam pipes, oily waste, etc. If coal can be got into the pile in pieces that will stay on a $^3/_4$-in. bar screen there will be no heating. The pile may be of any height provided there be no fines. Where mixed lump and fine coal must be stored the pile should be so built as to avoid segregation of sizes. The production of fresh surfaces by breakage just before going into storage, predisposes to spontaneous combustion unless the crushing is so fine and the packing of the pile so dense as to largely exclude air circulation. Coal should be so stored that its temperature conditions can be daily inspected. When any portion reaches a temperature of 140 or 150 deg. fahr. there is a high probability that within a few days or weeks a destructive temperature will be reached. If the temperature reaches 160 or 180 deg. fahr., there is almost a certainty that a destructive temperature will be reached. The best remedy is to move the warm coal so that it may cool.

The possibility of quick removal should be considered in storing coal. This factor, rather than any tendency to heating, determines the desirable size of pile and its height. The tendency to heat differs in different coals, and experience is so far the best guide in determining this difference.

Notes on the Fatigue of Metals

By J. M. Lessells,[1] East Pittsburgh, Pa.

In all previously published work on the fatigue of metals in which the results of experiment or theory have been discussed, so far as the author is aware, attempts have been made to show that the endurance limit of a material is related to ultimate stress in tension alone. An exception must be made in the case of Bauschinger, however, who does not subscribe to this theory.

The results of experiments recently undertaken in the Research Laboratory of the Westinghouse Elec. & Mfg. Co. would indicate that this relation is not a simple one and that although the value of the ultimate stress in tension determines in large degree the value of the endurance limit, there are nevertheless other factors involved. These appear to be the microstructure of the material and also the magnitude of the internal stress to which it is subjected. Experimental results will be discussed to substantiate these conclusions.

Experimental Results

The following results were obtained from material drawn from the same heat of steel, the analysis of which was as follows: C, 0.37; Mn, 0.53; Si, 0.028; S, 0.033, and P, 0.013. One bar of this material was machined into test pieces in the rolled condition; another was annealed; a third was normalized, and the others were given heat treatments such that the quenching temperature was the same but the drawing temperature was varied to give different physical values. After treatment these bars were also machined into test pieces. Table 1 gives the tensile-test results obtained

TABLE 1 RESULTS OF TENSILE AND FATIGUE TESTS OF 0.37 C STEEL IN THE PEARLITIC STATE

No.	Treatment	Elastic limit, lb. per sq. in.	Yield point, lb. per sq. in.	Ultimate strength, lb. per sq. in.	Elongation, per cent	Reduction of area, per cent	Ratio $\frac{Y.P.}{E.L.}$	Endurance limit, lb. per sq. in.
1	As rolled	30,000	36,300	75,700	31.4	49.0	1.20	28,000
2	As annealed	34,700	37,000	88,700	32.3	48.0	1.07	28,600
3	As normalized	34,725	39,450	78,800	31.0	48.6	1.13	29,300

from the first three bars, rolled, annealed, and normalized, i.e., pearlitic steel, as well as the endurance values obtained on the same material in a White Souther cantilever fatigue-testing machine,

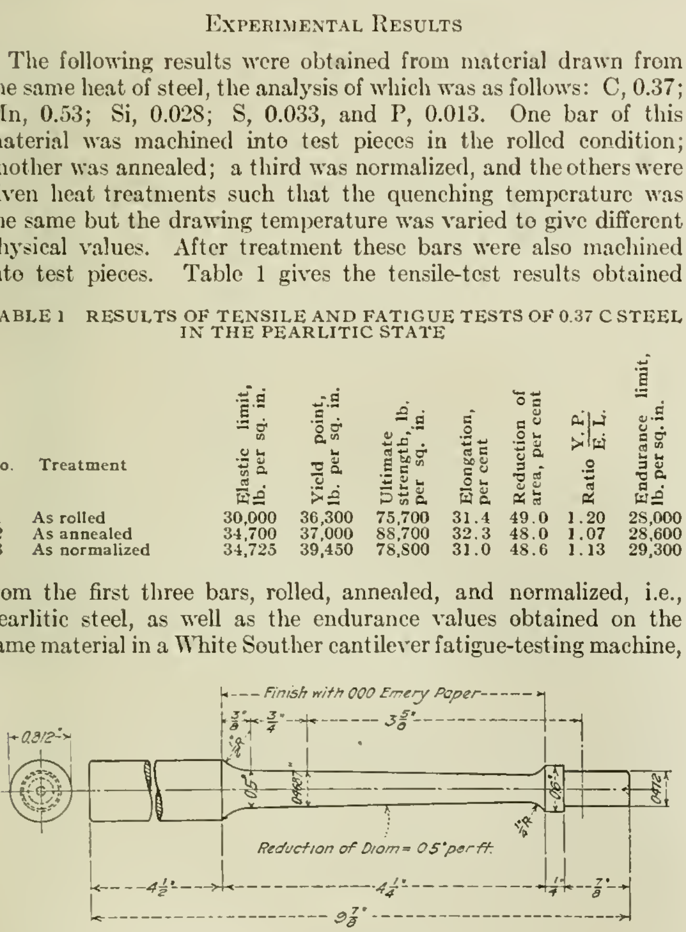

Fig. 1 Cantilever Test Piece Used in Fatigue Tests

using the test piece shown in Fig. 1. The endurance values were taken from curves such as those shown in Fig. 2, where the endurance limit is that stress which the material will withstand for at least 20×10^6 cycles of stress.

TABLE 2 RESULTS OF TENSILE AND FATIGUE TESTS OF 0.37 C STEEL IN THE SORBITIC STATE

No.	Treatment	Elastic limit lb. per sq. in.	Yield point, lb. per sq. in.	Ultimate strength, lb. per sq. in.	Elongation, per cent	Reduction of area, per cent	Ratio $\frac{Y.P.}{E.L.}$	Endurance limit, lb. per sq. in.
4	Quenched in water and drawn	64,600	69,460	105,460	21.8	56.1	1.07	50,000
5		65,600	74,660	114,100	17.7	49.0	1.14	49,000
6		68,000	80,800	116,800	16.4	40.9	1.185	51,000
7		74,000	92,000	130,000	12.4	34.6	1.24	58,000[a]

[a] Troostite present.

[1] Westinghouse Research Laboratory.

Table 2 gives the tensile-test results obtained from the three remaining bars which received different heat treatments, i.e., sorbitic steel, together with the endurance values for these steels obtained in a manner similar to that previously described.

Theory from Experiment

It would be well before these results are discussed to review some of the theory of the subject. Examining Gerber's parabolic formula, if

f_e = endurance stress
r = range of stress
F = maximum stress in tension, and
n = constant depending upon carbon content,

$$f_e = \frac{r}{2} + \sqrt{F^2 - nrF}$$

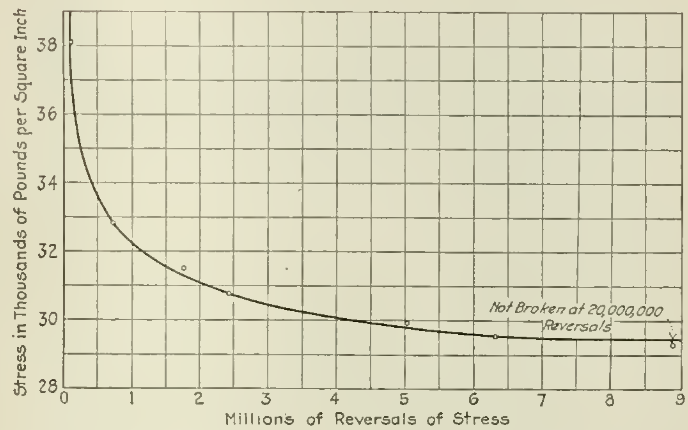

Fig. 2 Endurance Curve for 0.37 C Steel as Normalized

and if this stress is completely reversed,

$$r = f_e - (-f_e) = 2\,f_e$$

$$f_e = f_e + \sqrt{F^2 - 2nFf_e}$$

or

$$f_e = \frac{F}{2n}$$

which indicates that the endurance limit for a given steel is dependent upon the maximum stress in tension alone. This is not now in accordance with experimental results and does not take account of the structure and the magnitude of the internal stress. Considering these influences, experimental results obtained will now be discussed. Steels having the same microstructure will be grouped together, either as pearlitic, sorbitic, or troostitic steels. Moreover, from observations made on various series of tensile-test diagrams it is believed that the ratio x of yield point to elastic limit is a measure of the internal stress in the material. It is a well-known fact that with a perfectly annealed steel (zero internal stress) this ratio is unity, and in a quenched material it is high (high internal stress) as shown by the rounded diagram of elastic extension.

Application of Theory

Taking the material in the rolled state as the basis, then, from Table 1,

$$x_1 = \frac{\text{yield-point stress}}{\text{elastic-limit stress}} = 1.2$$

$$f_1 = 28{,}000 \text{ lb. per sq. in.}$$

$$F_1 = 75{,}700 \text{ lb. per sq. in.}$$

whence

$$k_1 = \frac{28{,}000}{75{,}700} = 0.37$$

Then, using these data, the endurance limit for the annealed state can be calculated as follows from the tensile-test data:

$$x_2 = 1.07$$
$$F_2 = 68{,}700 \text{ lb. per sq. in.}$$

whence

$$f_2 = 68{,}700 \times k_1 \times \frac{x_1}{x_2}$$
$$= 68{,}700 \times 0.37 \times \frac{1.20}{1.07}$$
$$= 28{,}500 \text{ lb. per sq. in.}$$

The value of f_2 obtained by experiment, as shown in Table 1, is 28,600 lb. per sq. in.

For the normalized state

$$x_3 = 1.13$$
$$F_3 = 76{,}800 \text{ lb. per sq. in.}$$

whence

$$f_3 = 76{,}800 \times k_1 \times \frac{x_1}{x_3}$$
$$= 76{,}800 \times 0.37 \times \frac{1.20}{1.13}$$
$$= 30{,}000 \text{ lb. per sq. in.}$$

The value obtained for f_3 in the tests was 29,300 lb. per sq. in.

Taking the material in the No. 4 condition as the basis,

$$x_4 = 1.07$$
$$f_4 = 50{,}000$$
$$F_4 = 105{,}460$$
$$k_4 = 0.474$$

Then, using this as a basis,

$$x_5 = 1.14$$
$$F_5 = 114{,}100$$
$$= 114{,}100 \times 0.474 \times \frac{1.07}{1.14}$$
$$= 50{,}600 \text{ lb. per sq. in.}$$
$$= 49{,}000 \text{ lb. per sq. in. by experiment, Table 2.}$$

Taking the sixth condition,

$$x_6 = 1.185$$
$$F_6 = 116{,}800$$
$$f_6 = 116{,}800 \times 0.474 \times \frac{1.07}{1.185}$$
$$= 50{,}000 \text{ lb. per sq. in.}$$
$$= 51{,}000 \text{ lb. per sq. in. by experiment, Table 2.}$$

Taking the seventh condition,

$$x_7 = 1.24$$
$$F_7 = 130{,}000$$
$$f_7 = 130{,}000 \times 0.474 \times \frac{1.07}{1.24}$$
$$= 53{,}000 \text{ lb. per sq. in.}$$
$$= 58{,}000 \text{ lb. per sq. in. by experiment, Table 2.}$$

The reason why the value of the seventh series does not agree with experiment is because due to the drastic quenching given the material for this series there is troostite present and the value for the constant k will be greater than 0.455. From results available on other steels there is reason to believe that this will become 0.52, in which case

$$f_7 = 130{,}000 \times 0.52 \times \frac{1.07}{1.24}$$
$$= 58{,}500 \text{ lb. per sq. in.}$$

which agrees with the experimental value.

Table 3 gives the tensile and endurance values for a chromium stainless steel. In this case it will be noted that the only difference in the tensile-test values is in that of the elastic limit, the values of the yield points being nearly alike and the value of the ultimate stress being actually lower for the second steel. Nevertheless, this second steel is 50 per cent higher in fatigue-resisting properties than the steel designated No. 1.

Applying the theory again to these cases and taking average values from Table 3,

TABLE 3 RESULTS OF TENSILE AND FATIGUE TESTS ON CHROMIUM STEEL

No.	Elastic limit, lb. per sq. in.	Yield point, lb. per sq. in.	Ultimate strength, lb. per sq. in.	Elongation, per cent	Reduction of area, per cent	Endurance limit, lb. per sq. in.
1	21,000	49,000	89,150	24.2	48.6	32,500
1	36,000	51,600	88,200	23.7	55.2	32,500
2	47,500	51,000	82,800	34.2	66.6	50,000
2	45,000	51,750	83,100	33.2	67.9	50,000

$$x_1 = \frac{50{,}000}{28{,}000} = 1.78$$
$$f_1 = 32{,}500 \text{ lb. per sq. in.}$$
$$F_1 = 88{,}500 \text{ lb. per sq. in.}$$
$$x_2 = \frac{51{,}000}{46{,}000} = 1.1$$
$$F_2 = 83{,}000 \text{ lb. per sq. in.}$$

therefore

$$f_2 = 83{,}000 \times 0.367 \times \frac{1.78}{1.1}$$
$$= 49{,}400 \text{ lb. per sq. in.}$$

which again agrees with the result of experiment.

Certain of the results published by Professor Moore in Bulletin No. 136 of the University of Illinois are given in Table 4. In this case

TABLE 4 RESULTS OF TENSILE AND FATIGUE TESTS ON CARBON STEEL

(From Bulletin No. 136, Univ. of Ill. Engineering Equipment Station)

Steel	State	Elastic limit, lb. per sq. in.	Yield point, lb. per sq. in.	Ultimate strength, lb. per sq. in.	Ratio $\frac{\text{Y. P.}}{\text{E. L.}}$	Ratio of endurance limit to ultimate strength
0.37 C	As normalized	34,500	34,900	71,900	1.01	0.460
0.52 C	As normalized	45,500	47,600	98,000	1.05	0.428
0.93 C	As normalized	28,000	33,400	84,100	1.19	0.363
1.20 C	As normalized	58,600	60,700	116,900	1.04	0.427

also it will be seen that for steels having the same structure the ratio of endurance limit to the ultimate stress in tension is highest when the ratio of the yield point to elastic limit is the lowest. This again confirms what has been advanced in this discussion.

It is therefore believed by the author that the results he has presented are sufficient justification for the following conclusions: namely,

1 The breakdown of metal by fatigue is very highly localized, as evidenced by micro-examination of a test piece in the region of fracture failing to show an abnormal structure. It is therefore logical to believe that the limiting value of the fatigue stress will be some factor of the maximum stress in tension.

2 In the material examined (0.37 C) the fatigue stress has a maximum value, being higher for the sorbitic and troostitic states than for the pearlitic. It therefore follows that structure has a distinct effect.

3 For a given microstructure the value of the fatigue stress is influenced by the magnitude of the internal stress in the material initially due to the treatment which it has received. The ratio of yield point to elastic limit can be used to define the degree of this stress.

4 It therefore follows that if a tensile-test diagram for the annealed condition is available together with a microphotograph and the experimental value of the endurance limit for that state, then the endurance limits for all such similar microstructures can be predetermined from tensile-test diagrams for these other states.

According to tests carried out at the National Physical Laboratory, a solid gravel concrete wall and a wall of sand-lime bricks transmit about the same amount of heat under the same conditions, but a wall of stock bricks only transmits about three-quarters as much heat. A cavity wall of ordinary type transmits about half to five-eighths that of a solid wall, according to the size of the cavity.—*The Engineer*, Oct. 5, 1923, p. 367.

The Unilateral System of Tolerances

This System Favored by Majority of Firms in the United States Because of Its Economy and Freedom from Confusion

By EUGENE C. PECK,[1] CLEVELAND, OHIO

WHY do we need a national standard system of dimensional tolerances? What part do these tolerances play in the commerce and manufacture of the world?

They are needed for many purposes too numerous to discuss in this brief article, but the most important or primary reason for the use of standard systems of tolerances is to make possible interchangeable manufacture. No discussion of any tolerance system should have recognized weight which does not have interchangeability as its ultimate goal.

The greatest economic use of labor is found in quantity production of mating parts by interchangeable manufacture. This method of manufacture also gives to the consuming public the greatest value for the purchase price and the best service in renewal of repair parts. As a direct result of interchangeable manufacture the cost of many commodities has been brought within the means of the general public, thereby still further increasing the economics to be derived from quantity production.

Interchangeability Defined

There are several degrees of interchangeability. Strictly speaking, interchangeability consists in making the different parts of a mechanism so uniform in size and contour that each part will fit and properly function in any one of the whole number of mating parts, no matter when or where it is made. It will be noted that this definition means that each part of the mechanism of a certain model will fit any of the mechanisms of the same model, regardless of the lot to which it belongs or the year in which it was made. However, as often defined, interchangeability consists in making each part fit any mechanism in a certain series; that is, the interchangeability exists only in the same series.

Selective assembly is sometimes termed interchangeability, but it is merely assembly without fitting. It is used where close work and good fits are desired and consists in selecting by trial the largest internal members and assembling them with the largest external members, thus limiting the freedom of fits and still allowing a reasonable tolerance in machining. The following example will serve as an illustration: If ten 1-in. holes should vary from standard size to 0.001 in. oversize and ten shafts were selected from a lot which gave the desired kind of fit in each pair of mating parts, they would function properly without fitting; but it is evident that the largest of these shafts would not interchange with the smallest holes and give the desired results if good fits were required. Therefore interchangeability by this method is very limited and should be so recognized.

It will be noted that the strict definition of interchangeability given above does not imply that the parts must always be made without hand work, although that is usually considered desirable. It does mean, however, that when the mating parts are finished, by whatever process, they must assemble and function properly, without fitting individual parts one to the other. On this point hinge some of the controversies on interchangeable manufacture and the advisability of its application.

It must be realized that the rapid production of a large number of interchangeable parts such as was demanded during the World War necessitates their manufacture in a number of separated shops. For all of these parts to be within the specified limits for size requires that each shop must first have master gages representing as exactly as possible these limits. To produce a number of master gages which shall be identical within very close limits presupposes the existance of linear standards that are accurate and identical all over the manufacturing world, or else the production of the master gages by a single concern which has accurate standards.

In a pair of mating parts that move freely, there is a space or clearance between the mating surfaces. This space is large or small according to whether the fit is loose or tight. If this space be gradually reduced, a condition will ultimately be reached in which there is no space or clearance between mating surfaces, that is, they fit metal to metal without shake. Then any movement of the mating parts one within the other will require some force, and if the surfaces are accurate and smooth, both members are then of the same size. The dimensions of the parts making this fit should then be regarded as having the exact standard or basic size.

This is the place at which interference of metal begins, often termed the zero point or zero line. Tolerances and allowances are considered as plus above this line and minus if below it.

This zero line is then the place at which interference of metal begins to take place, and it should represent the exact standard or basic value of the dimensions because a correct pair of mating standard gages check the dimensions of a pair of mating parts against interference. This means that the minimum dimension of the external member and the maximum dimension of the internal member of a pair of mating parts that fit without shake are standard or basic. This fit without shake is the most difficult class of fit to make. The standard gages purchased in the open market are the "go" gages for this fit and serve to check for an interference of metal.

Strict interchangeability can be maintained only when the interference of metal between mating parts takes place at a point which bears a fixed relation to the basic or standard dimension. This is so obvious that it scarcely even needs explanation. It must be plain that if every firm agreed that the zero or interference line should be 0.001 in. over basic and worked to this system, universal interchangeability could be maintained. It must be equally plain that if one firm adopted the plan of having the zero line or point at which interference takes place 0.001 in. over basic or standard, another 0.001 in. below basic or standard, and still another at a point exactly agreeing with basic or standard, there could be no strict interchangeability of mating parts among these three firms. Such a condition is exactly analogous to a variation in the values of linear standards. If the American inch was 0.001 in. smaller than the British and 0.002 in. smaller than the French, interchangeability of product among these countries would be lost, even though the workmanship was perfect in each case.

This feature of having the basic or standard gage determine the line at which interference of metal takes place is quite valuable, because these gages alone will check product against interference and the mating parts are bound to go together. It should be noted that there is a very large amount of work made all over the country in which fits are not essential but the parts *must go together freely*. Therefore for this interchangeability and the maintenance of nominal-sized product it is a great advantage to be able to inspect against an interference with a set of standard basic gages.

Two Tolerance Systems Compared

It seems impossible to put too much emphasis on the basic or fundamental fact that where interchangeability is desired there must be a fixed and unchanging point in relation to the basic or standard at which the interference of metal takes place. The master gages or standard gages of nominal sizes ordinarily available everywhere conform to the fundamental condition that they are produced under ideal conditions and are identical within any limits now being discussed. A system dependent directly on these standard gages for checking the wear limit of the "go" gages is inherently superior to one dependent on another set of master gages whose limits are at variance with the standard gages of nominal size.

The Unilateral System of tolerances complies exactly with this basic principle, while the Bilateral System violates it.

[1] General Supt., Cleveland Twist Drill Co. Chairman, A.S.M.E. Standardization Committee; chairman, Sectional Committee on the Standardization of Plain Limit Gages for General Engineering Work; vice-chairman, National Screw Thread Commission.

Strict interchangeability demands control of the dimensions of the minimum external and maximum internal members. If the interference of metal is intentional, as in tight fits, control of these two dimensions is also the important factor as well as in free fits in order to prevent the assembly of mating parts that are too tight. There should be no confusion or misunderstanding in regard to the assembly of mating parts by interchangeable manufacture—the parts will assemble and function when no external member is smaller than the prescribed limit, and no internal member is larger than the prescribed limit. No gaging system can be set up, however, which depends on the use of worn gages, because gages do not wear uniformly in either size or contour and hence cannot control either of the limiting dimensions when worn. It is a delusion to think that either on account of gage wear, gage tolerance, or for any other reason, the zero point can be crossed without destroying practical and economical interchangeability.

For analysis and comparison consider a hole made for three classes of fit: snug, 1.000 in. ± 0.0005; free, 1.000 in. ± 0.001; loose, 1.000 in. ± 0.002, as dimensioned by the Bilateral System. A glance indicates immediately three minimum as well as three maximum holes. The zero point or interference of metal takes place respectively 0.0005 in., 0.001 in. and 0.002 in. below the basic size of 1.0000 in. This will require three "go" gages none of which are basic, all being special. The resulting pieces if made in large quantities will have to be stored separately to obtain the kind of fit desired and to prevent an interference of metal with shafts made for a higher grade of work.

The limit gages used in this system cannot be handed down to the next succeeding poorer grade of fit without refinishing because they will be worn to a taper. There will also be the cost of remarking them for the new class of fit. The same may be also said of the solid reamers. From the largest solid reamer that could be used to the smallest for all three fits, before it is thrown away, there is a wear of 0.004 in. under ideal conditions.

Using the same example but the Unilateral System of tolerances, the hole dimensions become:

$$\text{Snug Fit, 1.000 in.} \begin{matrix} +0.001 \\ -0.000 \end{matrix} \qquad \text{Free Fit, 1.000 in.} \begin{matrix} +0.002 \\ -0.000 \end{matrix}$$

$$\text{Loose Fit, 1.000 in.} \begin{matrix} +0.004 \\ -0.000 \end{matrix}$$

We have at once one uniform minimum hole and that is basic 1.0000 in. The Standard 1 in. plug is the "go" gage for all three classes of fits. The interference of metal takes place at the same unvarying zero point, the basic dimension. There is required one standard gage for the "go" gage which can be bought in the open market, for all three fits as against three special "go" gages for the Bilateral System. There is, however, no difference in gage cost in either system for the "not go" gages.

In manufacture the holes are quite commonly and may well be made with the same tools; inspection will pass, in either system, all holes which the "not go" gage for the snug-fit class will not enter.

In the Unilateral System if the same "go" gage accepts all of these pieces as well, every one of them can be used for interchangeable assembly for any one of the three classes of fits without further classification. In the Bilateral System three inspections with three different "go" gages will have to be made and the holes belonging to each class of fit kept separate with the attendant trouble and losses. It is claimed by the opponents of the Unilateral System that this method of inspection will pass more pieces by the Bilateral System, but this is not true as a little thought will show. The machining ability of the operator being equal in each case, the same number will be passed by each system as the extreme tolerance limits are the same, 0.004 in. in each case.

The wear life of a tool depends, all factors being equal in each case, on the amount the tool is over the minimum hole size at the beginning of its life, and not on the relation of the size to the basic or standard. It is the practice in the United States to make all solid reamers slightly over basic for wear life, and not exactly standard, as some engineers suppose.

In interchangeable manufacture in the United States it is the predominating practice to use adjustable reamers, returning them to the toolroom for correction as soon as the standard plug gage will not enter the holes. Years of experience have made plain that this procedure maintains accuracy and quality of holes at a low cost, at the same time makes possible the transfer of the skill of a good toolmaker through the toolroom to the machine operators, and best of all provides for strict interchangeability.

Indicating Tolerances

It will now be shown that the work of dimensioning and revising tolerances on drawings is less for the Unilateral System, requires less mental effort, and therefore tends toward economy and accuracy.

It is almost universally agreed that *allowance* or minimum clearance is a designer's term and from his standpoint the important factor in a fit. This is certainly true if the designer is really competent, and as he is responsible for the proper functioning of the mechanism he has a right to insist on the accepted fundamental, namely, that allowance (neutral zone or minimum clearance) must never be encroached upon from any cause.

The important factor, from the manufacturing standpoint, is the *tolerance* allowed.

Thus allowance and tolerance are each required by two different parties, sometimes so widely separated as to never even see each other. They must not therefore be confused nor tampered with by the wrong party or trouble will ensue.

To illustrate, let it be assumed that a designer desires a hole with a free-running shaft and has decided that an allowance of 0.001 in. is sufficient. That is, he will make the hole 1.000 in. standard and the shaft 0.999 in. This represents his ideal condition of this pair of mating parts for the job intended. If he plans to make only one pair, this is all that is necessary and the toolmaker could make the parts without trouble. This establishes the fact that 0.001 in. is the clearance between the mating surfaces of this pair, and this is the minimum requirement.

Suppose, however, it is desired to make, say, 10,000 of these pairs and it is decided to allow 0.001 in. tolerance on each member. The dimensions then become (by the Unilateral System):

$$\text{Hole, 1.000 in.} \begin{matrix} +0.001 \\ -0.000 \end{matrix} \qquad \text{Shaft, 0.999 in.} \begin{matrix} +0.000 \\ -0.001 \end{matrix}$$

It will be seen from the above that the main dimensions show at a glance what is the allowance, or the tightest fit. Attention is also called to the fact that these main dimensions also represent what is commonly called "maximum metal." Increasing the metal in either member will make a tighter fit than is permissible. This, then, should be the rule for dimensioning drawings: Main figures indicate maximum metal or tightest fit permissible.

Tolerance should always be applied in a direction to produce greater looseness of fit, as this is the only sacrifice that can be permitted for variation in manufacture.

If for any reason tolerances must be changed, a single dimension only for each member need be altered and the tightest fit is not interfered with. It will be noted that changing the tolerances on either of these members permits the use of the same "go" gages without change.

In the Bilateral System the designer, having established his tightest fit at the same dimensions, i.e., hole 1.000 in., shaft 0.999 in., applies the tolerance to the hole 1.000 in. $\pm$ 0.0005 in. and this establishes his minimum hole as 0.9995 in., from which he subtracts 0.001 in. for his allowance. This gives him the maximum shaft 0.9985, from which he again subtracts his 0.001 in. tolerance, arriving at the minimum shaft as 0.9975 in. He may dimension these parts several ways thus:

$$\text{Hole} = 1.000 \text{ in} \pm 0.0005 \text{ in.} \qquad \text{Shaft} = 0.999 \pm 0.0005 \text{ in.}$$

$$\text{or Hole} = \begin{cases} 1.0005 \text{ in.} \\ 0.9995 \text{ in.} \end{cases} \qquad \text{Shaft} = \begin{cases} 0.9985 \text{ in.} \\ 0.9975 \text{ in.} \end{cases}$$

$$\text{or Hole} = 1 \text{ in.} \pm 0.0005 \text{ in.} \qquad \text{Shaft} = 1 \text{ in.} \begin{matrix} +0.0015 \text{ in.} \\ -0.0025 \text{ in.} \end{matrix}$$

In none of these can the tightest fit be determined without considerable mental effort. Changing the tolerances on the hole means changing one dimension by the first and third method of dimensioning, two by the second method. Changing the tolerance on the shaft when the hole has been changed as well, means changing two dimensions regardless of which of the three methods are used, with

the attendant extra care and chance for error. Attention is also called to the fact that changing the tolerance destroys the old zero point at which interference of metal takes place and sets up a new one which may in many cases prevent the assembly of parts previously accepted. Such a change would plainly destroy the assurance that renewals would fit the original parts. It should be noted also that both the "go" and "not go" gages for each member are no longer acceptable under the new dimensions, but must be retained for use in making repair parts for those mechanisms made before the tolerances were changed.

Summary

The experience of the writer, covering thirty years of active work in connection with both the making and the use of tools for accurate manufacturing by all of the systems in use during that time, leads him to believe beyond question that the Unilateral System of tolerances has the following proven advantages:

a It provides the only practical means of maintaining strict interchangeability in manufacture.

b It is more economical to manufacture by this system due to its simplicity.

c The gage cost is less.

d The cost of dimensioning drawings is less.

e The mental effort of dimensioning drawings is less.

f Tolerances may be changed without destroying the zero point at which interference takes place. Changing the position of this zero point may prevent the assembly of parts already made.

g Permits the standard calibrated gage to settle any controversy regarding the interference of metal between mating parts.

h Permits the standard calibrated gage to control the minimum dimensions of the external member.

i Simplifies the handling of small tools and gages in the toolroom.

Basic Hole or Basic Shaft

There seems to be some confusion in the minds of many concerning the relation between the adoption of a standard tolerance system and the decision as to which of the two mating parts should be considered basic. Or in other words, which side of the zero line the tolerance for a free running fit should be placed.

If the allowance is taken from the shaft or internal member, the minimum hole becomes basic. If, on the other hand, the allowance or neutral zone is obtained by removing various amounts of metal from the hole or external member, the maximum shaft becomes basic.

In the writer's opinion there has been altogether too much controversy over basic hole and basic shaft. As a matter of fact there are conditions under which both the hole and shaft are basic and there are conditions under which neither of them is basic.

It must be understood that neither shafts nor holes can be made in quantity without a tolerance. This being true, there can literally be no basic hole or basic shaft. However, as shown in the preceding part of this article, in the actual fit of metal to metal both hole and shaft are basic. In all of the other fits the minimum hole only is basic, the tolerance permitting the holes to be above basic.

It is believed that in the foregoing part of this article it has been shown that the most economical practice and true interchangeability are best obtained by having the interference of metal take place at the basic dimension. This, then, seems to be the governing point, and there is only one exception to the universal application of this rule. This exception is transmission shafting or its equivalent, in which a commercial article is used in a way that requires a variety of fits on the same member. This forms a special case in which the holes may well be made to suit this uniform internal member.

However, standard shafting is now and has always been intended to be made to the basic size with the tolerance minus, and this practice does not entirely substitute basic shaft for basic hole, because some of the shafting will be undersize on account of using the tolerance, and hence will produce a more or less free fit. The shafting never being over basic means that a drive fit could only be made with a hole smaller than basic, hence this part of the manufacture would involve a slightly special case. This special case need not, however, interfere with the general standard system as outlined above, because it belongs in a class of machinery slightly divorced from the manufacture of interchangeable machine parts.

The writer's opinion is that the sooner basic hole or basic shaft is forgotten the sooner we can get down to a usable and workable system.

Made-to-order material including fits is not to be confused with the interchangeable product previously referred to. Made-to-order fits can only be made to the dimensions given or to fit a sample submitted. These, then, belong to no system of fits or tolerances and it matters little whether the shaft or hole is basic.

The great bulk of manufactured mating parts are most economically made, and interchangeability is best maintained when the minimum hole is basic and the interference of metal begins at this basic dimension.

Standard Tolerances and Allowances for Machined Fits

First Report of Sectional Committee on the Standardization of Plain Limit Gages for General Engineering Work Now Before the Sponsor Body for Approval

At the present time much thought is being given to this subject by the manufacturers of Europe and the United States. The report of this Sectional Committee will accordingly be received with considerable interest.

This Sectional Committee was organized under the procedure of the American Engineering Standards Committee in the Spring of 1920 by The American Society of Mechanical Engineers acting as the Sponsor body. The Committee is headed by E. C. Peck as chairman and H. W. Bearce as secretary, and the scope of this project as published by the A. E. S. C. is "The standardization of the nomenclature and classification of cylindrical machine fits, including allowances and tolerances, for interchangeable manufacture classification, and fixing of standard tolerances for plain limit gages; methods of gaging these classes of fits."

It is obviously impossible for us to reproduce in "Mechanical Engineering" the complete report of the Sectional Committee. We are, however, printing the entire text of the report and three of the tables to indicate the complete way in which this Committee now presents the results of its three years' study. The report having been unanimously approved by the members of the Committee, is before the Sponsor for approval and submission to the A. E. S. C. After such approval it will be published in pamphlet form, and it is hoped that these pamphlets will be ready for distribution shortly after the first of the new year. Those desiring copies should apply to The American Society of Mechanical Engineers.

Standard Tolerances and Allowances

Introductory

The Committee on Plain Gages for Engineering Work believe that the terms and definitions used should, as nearly as possible, conform to those in common use. The coining of new terms should be avoided as far as possible, and, where a choice of terms is available, weight should be given the term being the most significant or subject to the least misconstruction. With these ideas in mind, the following fundamentals and definitions have been adopted.

Fundamentals

Direction of Tolerance on Gages. 1 The extreme sizes for all plain limit gages shall never exceed the extreme limits of the part being produced. All variations in the gages, whatever their cause or purpose, shall bring these gages within these extreme limits. Thus a gage which represents a minimum limit may be larger,

but never smaller, than the minimum size specified for the part being produced; while the gage which represents a maximum limit may be smaller, but never larger, than the maximum size specified for the part being produced.

2 Temperature at Which Gages Shall Be Standard. This Committee recommends the use of 68 deg. fahr. (20 deg. cent.)

3 The final result sought by gaging is interchangeable manufacture in some degree. This means that the parts of a mechanism can be assembled without *fitting* one part to another and when assembled the mechanism will function properly.

4 Applied to manufactured material, the result sought is sufficient uniformity in size and contour to adapt the material to the requirements of the industries without further fitting. The fundamental principle involved in interchangeable manufacture requires that "a system of standardization and classification of fits must establish a clearly defined line at which interference between mating parts begins." Hence,

(*a*) The standard or basic size, as physically represented by a correct standard master gage, represents the line at which this interference begins between mating parts.

(*b*) It is the minimum size of the external members of all mating parts of standardized practice, regardless of the kind of fit.

(*c*) It is the maximum size of internal members of all mating parts where interference begins or that fit metal to metal.

The condition of (*b*) and (*c*) is represented by a mating pair of correctly fitting standard gages.

(*d*) The limits of the component as physically represented by the limit master gages must never be exceeded as a result either of error or wear of the gages.

(*e*) "Go" gages or the equivalent verification of all the factors involved in the fit are necessary to prevent interference of mating parts.

In the case of force fits, "go" gages are necessary to determine the maximum amount of interference between mating parts.

(*f*) "Not go" gages or the equivalent verification of the determining factor is necessary to prevent the maximum looseness of mating parts exceeding the limits specified.

In the case of force fits, "not go" gages are necessary to determine the minimum amount of interference between mating parts.

Definitions

1 *Gaging.* A process of measuring manufactured material to assure the specified uniformity of size and contour required by the industries.

2 *Gage.* A device for determining whether or not one or more of the dimensions of a manufactured part are within specified limits.

(*a*) *Ring Gage.* One with inside measuring surfaces circular in form. The measuring surfaces may be cylindrical or conical. The exterior shape or form of the gage is immaterial.

(*b*) *Plug Gage.* One with outside measuring surfaces arranged to verify the specified uniformity of holes. A plug gage may be straight or tapered and of any cross-sectional shape.

(*c*) *Receiving Gage.* One with inside measuring surfaces arranged to verify the specified uniformity of size and contour of any piece of manufactured material.

(*d*) *Indicating Gage.* One that exhibits visually the variations in the uniformity of dimensions or contour, the amount of the variation being measured by a graduated scale or by marks, such as, dial, lever, flush-pin, plunger gages, etc.

(*e*) *Snap Gage.* A fixed caliper with inside measuring surfaces for measuring diameters, lengths, thicknesses, etc.

(*f*) *Caliper Gage.* One which for internal members is similar to a snap gage, and for external members is similar to a plug gage.

3 *Standard.* A fixed physical value defined by the Government, such as the yard and meter.

4 *Standard Sizes.* A series of subdivisions of the yard and meter having correct values.

Note: The industries by common consent have chosen several different series important for interchangeable manufacture and when they have the correct value they are commonly called standard sizes. Such as: $^1/_8$ in., $^3/_{16}$ in., $^1/_4$ in., $^5/_{16}$ in., etc.

5 *Nominal Size.* A name given to the subdivision of the unit of length having no specified limits of accuracy but indicating a close approximation to a standard size.

6 *Basic Size.* The exact theoretical value from which all variations are made.

7 *Allowance.* A difference in dimensions of mating parts, the limits of which are prescribed. It is to provide for different kinds or classes of fits. It represents maximum tightness or minimum looseness.

Example: A shaft dimensioned 0.874 in. and a hole dimensioned 0.875 in. represents an allowance of 0.001 in. Using the same hole with a shaft dimensioned 0.876 in. represents an allowance of 0.001 in. also; but, as the shaft is larger than the hole, this allowance becomes a negative quantity.

8 *Tolerance.* A definite difference in the dimensions prescribed in order to permit variations in manufacture. It is equal to the difference between the maximum and minimum sizes.

Note: In the example under Allowance, the ideal condition has been given and the tightest fit permissible; but in manufacturing large numbers of pieces these sizes could not be produced exactly, so variations must be made that will not prevent their proper functioning but will enable them to be produced. These variations must therefore tend toward greater looseness. Therefore, if a manufacturing tolerance of 0.001 in. is required on each member, they would be dimensioned as follows:

Shaft	0.874 in.	+	0.000 in.
		−	0.001 in.
Hole	0.875 in.	+	0.001 in.
		−	0.000 in.

This defines a condition in which the greatest looseness in 0.003 in. and the greatest tightness is 0.001 in.

9 *Neutral Zone.* A space between the mating parts which is not to be encroached upon.

10 *Limits.* The extreme dimensions which are prescribed to provide for variations in fit and workmanship.

11 *Master Gage.* One whose gaging dimensions represent as exactly as possible any physical dimension of the component. It is the gage to which all other gages and all dimensions of manufactured material are finally checked or compared, either by direct check or comparison.

(*a*) *Reference Gage.* A commonly used name for master gage.

(*b*) *Check.* Another commonly used name for master gage.

(*c*) *Standard Master Gage.* Any master gage whose gaging dimensions have the standard or basic value of an established nominal size. The legal authenticity of a standard master gage should be established by having its deviations ascertained by the Bureau of Standards at Washington.

(*d*) *Limit Master Gages.* Gages which represent as nearly as possible the exact limiting physical dimensions of the manufactured material as established by the specified tolerances.

12 *Inspection Gages.* Gages for the use of the manufacturer or purchaser in accepting the product. They must not accept any product which the master gages will reject.

13 *Working Gages.* Gages used by the manufacturer to check the work as it is produced. They should not accept any product which the inspection gages will reject.

Classification of Fits

The following classification of fits is recommended:

Loose Fit (*Class 1*). This fit provides for considerable freedom and embraces those fits where accuracy is not essential.

Examples: Machined fits of agricultural and mining machinery; controlling apparatus for marine work; textile, rubber, candy, and bread machinery; general machinery of a similar grade; some ordnance material.

Free Fit—Liberal Allowance (*Class 2*). For running fits with speeds 600 r.p.m. or over, and journal pressures of 600 lb. per sq. in. or over.

Examples: Dynamos, engines, many machine-tool parts, and some automotive parts.

Medium Fit—Medium Allowance (*Class 3*). For running fits under 600 r.p.m. and with journal pressure less than 600 lb. per sq. in.; also for sliding fits; and the more accurate machine-tool and automotive parts.

Snug Fits—Small Allowance (*Class 4*). This is the closest fit which can be assembled by hand and necessitates work of considerable precision. It should be used where no perceptible shake is permissible and where moving parts are not intended to move freely under a load.

Wringing Fit—No Allowance (*Class 5*). This is also known as a

Table 1 Loose Fit (Class 1)

Diameter			Limits				Tightest Fit	Loosest Fit
From	Up to and Incl.	Mean	Hole		Shaft		Allowance	Allowance + Tolerances
			+	−	−	−	+*	+*
0	3/16	1/8	0.001	0.000	0.001	0.002	0.001	0.003
3/16	5/16	1/4	0.002	0.000	0.001	0.003	0.001	0.005
5/16	7/16	3/8	0.002	0.000	0.001	0.003	0.001	0.005
7/16	9/16	1/2	0.002	0.000	0.002	0.004	0.002	0.006
9/16	11/16	5/8	0.002	0.000	0.002	0.004	0.002	0.006
11/16	13/16	3/4	0.002	0.000	0.002	0.004	0.002	0.006
13/16	15/16	7/8	0.002	0.000	0.002	0.004	0.002	0.006
15/16	1 1/16	1	0.003	0.000	0.003	0.006	0.003	0.009
1 1/16	1 3/16	1 1/8	0.003	0.000	0.003	0.006	0.003	0.009
1 3/16	1 3/8	1 1/4	0.003	0.000	0.003	0.006	0.003	0.009
1 3/8	1 5/8	1 1/2	0.003	0.000	0.003	0.006	0.003	0.009
1 5/8	1 7/8	1 3/4	0.003	0.000	0.004	0.007	0.004	0.010
1 7/8	2 1/8	2	0.003	0.000	0.004	0.007	0.004	0.010
2 1/8	2 3/8	2 1/4	0.003	0.000	0.004	0.007	0.004	0.010
2 3/8	2 3/4	2 1/2	0.003	0.000	0.005	0.008	0.005	0.011
2 3/4	3 1/4	3	0.004	0.000	0.005	0.009	0.005	0.013
3 1/4	3 3/4	3 1/2	0.004	0.000	0.006	0.010	0.006	0.014
3 3/4	4 1/4	4	0.004	0.000	0.006	0.010	0.006	0.014
4 1/4	4 3/4	4 1/2	0.004	0.000	0.007	0.011	0.007	0.015
4 3/4	5 1/2	5	0.004	0.000	0.007	0.011	0.007	0.015
5 1/2	6 1/2	6	0.005	0.000	0.008	0.013	0.008	0.018
6 1/2	7 1/2	7	0.005	0.000	0.009	0.014	0.009	0.019
7 1/2	8 1/2	8	0.005	0.000	0.010	0.015	0.010	0.020

*(+) denotes clearance or amount of looseness.
Note: All dimensions in inches.

Table 2 Free Fit (Class 2)

Diameter			Limits				Tightest Fit	Loosest Fit
From	Up to and Incl.	Mean	Hole		Shaft		Allowance	Allowance + Tolerances
			+	−	−	−	+*	+*
0	3/16	1/8	0.0007	0.0000	0.0004	0.0011	0.0004	0.0018
3/16	5/16	1/4	0.0008	0.0000	0.0006	0.0014	0.0006	0.0022
5/16	7/16	3/8	0.0009	0.0000	0.0007	0.0016	0.0007	0.0025
7/16	9/16	1/2	0.0010	0.0000	0.0009	0.0019	0.0009	0.0029
9/16	11/16	5/8	0.0011	0.0000	0.0010	0.0021	0.0010	0.0032
11/16	13/16	3/4	0.0012	0.0000	0.0012	0.0024	0.0012	0.0036
13/16	15/16	7/8	0.0012	0.0000	0.0013	0.0025	0.0013	0.0037
15/16	1 1/16	1	0.0013	0.0000	0.0014	0.0027	0.0014	0.0040
1 1/16	1 3/16	1 1/8	0.0014	0.0000	0.0015	0.0029	0.0015	0.0043
1 3/16	1 3/8	1 1/4	0.0014	0.0000	0.0016	0.0030	0.0016	0.0044
1 3/8	1 5/8	1 1/2	0.0015	0.0000	0.0018	0.0033	0.0018	0.0048
1 5/8	1 7/8	1 3/4	0.0016	0.0000	0.0020	0.0036	0.0020	0.0052
1 7/8	2 1/8	2	0.0016	0.0000	0.0022	0.0038	0.0022	0.0054
2 1/8	2 3/8	2 1/4	0.0017	0.0000	0.0024	0.0041	0.0024	0.0058
2 3/8	2 3/4	2 1/2	0.0018	0.0000	0.0026	0.0044	0.0026	0.0062
2 3/4	3 1/4	3	0.0019	0.0000	0.0029	0.0048	0.0029	0.0067
3 1/4	3 3/4	3 1/2	0.0020	0.0000	0.0032	0.0052	0.0032	0.0072
3 3/4	4 1/4	4	0.0021	0.0000	0.0035	0.0056	0.0035	0.0077
4 1/4	4 3/4	4 1/2	0.0021	0.0000	0.0038	0.0059	0.0038	0.0080
4 3/4	5 1/2	5	0.0022	0.0000	0.0041	0.0063	0.0041	0.0085
5 1/2	6 1/2	6	0.0024	0.0000	0.0046	0.0070	0.0046	0.0094
6 1/2	7 1/2	7	0.0025	0.0000	0.0051	0.0076	0.0051	0.0101
7 1/2	8 1/2	8	0.0026	0.0000	0.0056	0.0082	0.0056	0.0108

* (+) denotes clearance or amount of looseness.
Note: All dimensions in inches.

"tunking fit" and it is practically metal-to-metal. Assembly is usually selective and not interchangeable.

Tight Fit—Slight Negative Allowance (*Class 6*). Light pressure required to assemble, and the fits are more or less permanently set. They are used for the fixed end of studs for gears, pulleys, rocker arms, etc., drive fits in thin sections, or extremely long fits in other sections. Used in automotive, ordnance, and general machine manufacturing. Also used for shrink fits on very light sections.

Medium Force Fit—Negative Allowance (*Class 7*). Considerable pressure required and the fits are considered permanently assembled. Used in fastening locomotive wheels, car wheels, armatures of dynamos and motors, and crank disks to their axles or shafts. Also used for shrink fits on medium sections or long fits.

Heavy Force and Shrink Fit—Considerable Negative Allowance (*Class 8*). Used for fits where metal will stand great stress and where a heavy force fit is impractical. Such as locomotive wheel tires, heavy crank disks of large engines, etc.

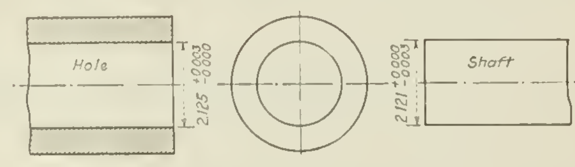

Fig. 1 Example of Loose Fit (Class 1)

	Hole	Shaft	
Tightest Fit	2.125	2.121	0.004 Allowance
Loosest Fit	2.128	2.118	0.010 Allowance + Tolerances

Formulas

When d = mean diameter,

$$\text{Hole Tolerance} = 0.0025\sqrt[3]{d}$$
$$\text{Shaft Tolerance} = 0.0025\sqrt[3]{d}$$
$$\text{Allowance} = 0.0025\sqrt[3]{d^2}$$

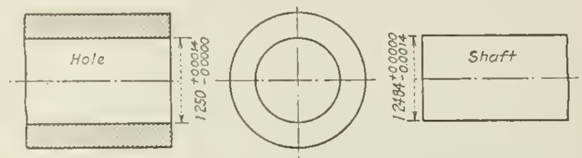

Fig. 2 Example of Free Fit (Class 2)

	Hole	Shaft	
Tightest Fit	1.2500	1.2484	0.0016 Allowance
Loosest Fit	1.2514	1.2470	0.0044 Allowance + Tolerances

Formulas

When d = mean diameter,

$$\text{Hole Tolerance} = 0.0013\sqrt[3]{d}$$
$$\text{Shaft Tolerance} = 0.0013\sqrt[3]{d}$$
$$\text{Allowance} = 0.0014\sqrt[3]{d^2}$$

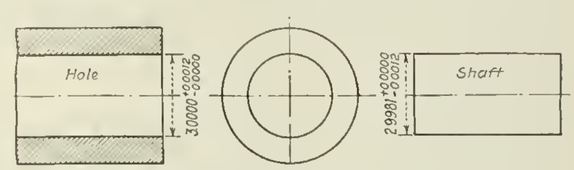

Fig. 3 Example of Medium Fit (Class 3)

	Hole	Shaft	
Tightest Fit	3.0000	2.9981	0.0019 Allowance
Loosest Fit	3.0012	2.9969	0.0043 Allowance + Tolerances

Formulas

When d = mean diameter,

$$\text{Hole Tolerance} = 0.0008\sqrt[3]{d}$$
$$\text{Shaft Tolerance} = 0.0008\sqrt[3]{d}$$
$$\text{Allowance} = 0.0009\sqrt[3]{d^2}$$

Table 3 Medium Fit (Class 3)

Diameter			Limits				Tightest Fit	Loosest Fit
From	Up to and Incl.	Mean	Hole		Shaft		Allowance	Allowance + Tolerances
			+	−	−	−	+*	+*
0	3/16	1/8	0.0004	0.0000	0.0002	0.0006	0.0002	0.0010
3/16	5/16	1/4	0.0005	0.0000	0.0004	0.0009	0.0004	0.0014
5/16	7/16	3/8	0.0006	0.0000	0.0005	0.0011	0.0005	0.0017
7/16	9/16	1/2	0.0006	0.0000	0.0006	0.0012	0.0006	0.0018
9/16	11/16	5/8	0.0007	0.0000	0.0007	0.0014	0.0007	0.0021
11/16	13/16	3/4	0.0007	0.0000	0.0007	0.0014	0.0007	0.0021
13/16	15/16	7/8	0.0008	0.0000	0.0008	0.0016	0.0008	0.0024
15/16	1 1/16	1	0.0008	0.0000	0.0009	0.0017	0.0009	0.0025
1 1/16	1 3/16	1 1/8	0.0008	0.0000	0.0010	0.0018	0.0010	0.0026
1 3/16	1 3/8	1 1/4	0.0009	0.0000	0.0010	0.0019	0.0010	0.0028
1 3/8	1 5/8	1 1/2	0.0009	0.0000	0.0012	0.0021	0.0012	0.0030
1 5/8	1 7/8	1 3/4	0.0010	0.0000	0.0013	0.0023	0.0013	0.0033
1 7/8	2 1/8	2	0.0010	0.0000	0.0014	0.0024	0.0014	0.0034
2 1/8	2 3/8	2 1/4	0.0010	0.0000	0.0015	0.0025	0.0015	0.0035
2 3/8	2 3/4	2 1/2	0.0011	0.0000	0.0017	0.0028	0.0017	0.0039
2 3/4	3 1/4	3	0.0012	0.0000	0.0019	0.0031	0.0019	0.0043
3 1/4	3 3/4	3 1/2	0.0012	0.0000	0.0021	0.0033	0.0021	0.0045
3 3/4	4 1/4	4	0.0013	0.0000	0.0023	0.0036	0.0023	0.0049
4 1/4	4 3/4	4 1/2	0.0013	0.0000	0.0025	0.0038	0.0025	0.0051
4 3/4	5 1/2	5	0.0014	0.0000	0.0026	0.0040	0.0026	0.0054
5 1/2	6 1/2	6	0.0015	0.0000	0.0030	0.0045	0.0030	0.0060
6 1/2	7 1/2	7	0.0015	0.0000	0.0033	0.0048	0.0033	0.0063
7 1/2	8 1/2	8	0.0016	0.0000	0.0036	0.0052	0.0036	0.0068

*(+) denotes clearance or amount of looseness.
Note: All dimensions in inches.

Explanatory Notes

In the table reproduced below many of the terms in common use in the shops of the country are given with the equivalent term which this Committee's report recommends:

Greatest Tightness Least Looseness Tightest Fit Neutral Zone Maximum Metal	Are all common terms which are the same as—	Allowance
Least Tightness Greatest Looseness Loosest Fit Minimum Metal	Are all common terms which are the same as—	Allowance Plus Tolerances
Difference between largest and smallest permissible size of either members. Variation in the size allowed	Now called—	Tolerance

The basis for the following recommended allowances and tolerances is classification of fits, quite commonly known to the manufacturing public. Interference between mating parts takes place at the exact basic value of the dimension; hence an accepted pair of mating standard gages become the "go" gages for mating parts which will prevent interference at the basic value of the dimension.

On account of the lack of a uniform and acceptable method of measuring the fitting surfaces of external members of a pair of mating parts, it is recommended that plugs, blocks, disks, and rods govern the checking of external members for the reason that usually the same measuring device will check for accuracy both the internal member and the gage for the external member, thus avoiding an interference when both members appear to have the same dimension.

To illustrate: If a 2-in. hole be measured with an inside micrometer and a shaft be measured with an outside micrometer, and both measure exactly 2 in., there is no assurance they will go together; but, unless there was a definite understanding in a contract, the pieces might be ruled acceptable by law. If, however, the 2-in. hole would receive a plug gage which measured exactly 2 in. by a measuring machine, it would also receive an accurately finished shaft of the same size when measured by the same machine.

It is well known that a correct pair of plug and ring gages 2 in. in diameter will each check parts that will go together. It is also well known that the character of fit depends on the rotundity, parallelism, size, and in some cases, contour of the mating parts, and that for cylindrical fits in mating parts, plug and ring gages are the only sure means of determining whether or not parts will go together. If either member of a pair of mating parts is three- or five-cornered, a snap gage or micrometer will not insure their going together.

In the following allowances and tolerances, the best practice available was considered, and where differences occurred a compromise was attempted. The tolerances on holes apply only to reamed holes, or holes having a finish equivalent to reaming. From the standpoint of satisfactory performance, the tightest and loosest fits permissible are the all-important considerations. From a manufacturing standpoint, tolerances are the important factors. Hence both the tightest and loosest fit permissible must combine the tolerances and allowance, and therefore both allowance and tolerance must be considered for all-around satisfactory conditions.

It is not deemed feasible at the present writing to lay down allowances and tolerances which will apply to all work. Many so-called standard fits are made in the industries which are not interchangeable, and an attempt to make them so would be prohibitive in cost. They do, however, require to be made on a production basis, and it is believed that the tables here given will be found to contain allowances and tolerances which are suitable for most work, even if some selection or individual fitting of parts is desired.

In choosing the class of fit for manufacture, the engineer should keep in mind that cost usually increases proportionately to the accuracy required, and no finer class of fit should be chosen than the functional requirements actually demand. It is axiomatic that the closer the fit the smaller the manufacturing tolerance, and usually the greater the cost. The length of engagement of the fit also plays an important part in the selection of the class of fit for a piece of work. It is obvious that a long engagement will tolerate more looseness than a short one, and due regard should be paid to this feature.

Proposed Standard Sizes of Wrench-Head Bolts and Nuts

Sub-Committee No. 2 of the Sectional Committee on Bolt, Nut, and Rivet Proportions has completed its preliminary investigations and is now sending out its tentative proposals in the form of an eight-page 9 by 12 in. pamphlet. This tentative report contains seven tables and four charts which compare present practice in the United States and Europe with the new proposals.

The tables of proposed standard sizes cover:

a Rough-square and hexagonal bolt heads and nuts
b Finished square and hexagonal bolt heads and nuts
c Finished light nuts
d Finished hexagonal and square machine-screw nuts
e Finished hexagonal and square cap screws
f Wrench openings.

These proposed standard sizes are intended for the use of all industries and the consequent replacement of the various existing standards now in use in these industries. In these early stages of its activity the Sub-Committee has worked in coöperation with the National Screw Thread Commission. The tables of sizes proposed have been tentatively considered and favorably received by that Commission. Some limited publicity has been given to the work of the Sub-Committee on Wrench-Head Bolts and Nuts, but it has seemed wise to the Sub-Committee that before final report is made to the Sectional Committee, it should have more universal criticism of the proposed standard sizes.

It has seemed wise to reduce the number of wrenches required through simplification of outside dimensions of bolts and nuts. This policy also tends to reduce the number of sizes of raw material which the bolt and nut manufacturer must carry in stock. In order to obtain this result, it has been necessary to depart from sizes calculated by formulas by $^1/_{32}$ in. for the smaller sizes of bolt heads and nuts and by larger amounts for the larger sizes. It will be noted that similar practice has been followed in the S.A.E. standard and in many foreign standards. The factor of safety in both heads and nuts appears sufficient to permit this.

It is hoped that criticism of the proposed dimensions with detailed reasons therefor will be made by both manufacturers and consumers, in order that the dimensions finally recommended as standard may meet as far as practicable with the approval of all.

Copies of this pamphlet may be obtained by addressing C. B. LePage, Assistant Secretary, The American Society of Mechanical Engineers, 29 West 39th Street, New York. Criticisms and comments should be sent to the Chairman at the same address.

A New Diagram for Water Vapor-Air Mixtures

By PROF. A. MOLLIER[1]

AT THE BASIS of all calculations dealing with water vapor-air mixtures (humid air) lies the Dalton law. It applies fully only to mixtures of perfect gases, i.e., gases which obey solely the equation of state $pv = RT$, and whose energy and heat content depend exclusively on temperature. Air obeys the laws of perfect gases, but water vapor deviates from them to a noticeable extent, the more so the higher its pressure and the lower its temperature. Because of this when we have to deal in engineering with water vapor-air mixtures wherein the partial pressure of the water vapor is of the order of several atmospheres, the precise calculation becomes difficult, as instead of the Dalton law and simple expressions for the energy and heat content of the mixture, it is necessary to deal with complicated and as yet comparatively little-known laws. As a matter of fact, however, in the vast majority of cases arising in practical engineering work, the partial pressure of the water vapor does not exceed 1 atmos. and at such a low pressure water vapor may be treated as a perfect gas in a manner that will not affect the precision of the results to any very great extent. This, of course, materially simplifies all calculations.

Quite frequently a somewhat different method is used. While the Dalton law is still used as a foundation, the volume and heat content of water vapor are computed not in accordance with the gas equations but (when the steam is in a state of saturation) are taken from steam tables. Since the proper handling of problems involving unsaturated (superheated) steam leads to excessively involved computations, however, it is customary to revert to the gas laws by assuming that the density of the steam at given temperature is proportional to the partial pressure and that the heat content is independent of the pressure. This procedure is, however, time consuming, lacking in proper checks, and full of internal contradictions. Furthermore, should water vapor-air mixtures become widely employed in engineering with such high partial pressures of water vapor that simple gas laws would no longer serve, it would become necessary to investigate critically the entire problem of the computation of their properties.

As a rule gases are miscible in all proportions. We express the composition of such mixtures by volumes, and the relation between the volumes is equal to the ratio of the partial pressure to the total pressure. As regards water vapor, however, it can be mixed with air only to a limited extent, because its partial pressure cannot be greater than the saturation pressure h corresponding to the given temperature. (The author gives all pressures in millimeters of mercury.) The partial pressure of water vapor h_D may, however, be smaller than the saturation pressure, and it is usual and convenient to express the partial pressure as a fraction of the saturation pressure h', that is, $h_D = \varphi h'$. When written this way the expression indicates how far the air is still from saturation by water vapor, this being due to the fact that according to the gas law φ expresses also the ratio of the vapor content in a given volume to the maximum quantity of vapor which may be contained therein. φ is therefore called the relative humidity or degree of saturation of the air.

Assume that a room of V cubic meters capacity contains a water vapor-air mixture of pressure h and absolute temperature $T = 273 + t$ deg. cent. We can apply the equation of state of gases to the total weight of the mixture and its two constituent parts. For air,

$$(h - \varphi h')V = 2.153\, G_L T \quad [1]$$

where $h - \varphi h' = h_L$, which is the partial pressure in millimeters of mercury, while G_L is the weight of air in kilograms. For steam,

$$\varphi h' V = 3.46\, G_D T \quad [2]$$

For the mixture,

$$hV = GRT; \quad R = \frac{2.153}{1 - 0.378 \dfrac{\varphi h'}{h}} \quad [3]$$

and

$$G = G_L + G_D = \frac{0.465\, h - 0.176\, \varphi h'}{T}\, V \quad [4]$$

In one cubic meter of moist air there are therefore $0.289 \dfrac{\varphi h'}{T}$ kg. or $289 \dfrac{\varphi h'}{T}$ grams of water vapor.

During the changes of state of water vapor-air mixtures the amount of air usually remains unchanged while the amount of water vapor present is increased through condensation or decreased through evaporation. Because of this it is customary to consider mixtures of this character as containing 1 kg. of air and variable amounts of water vapor. The amount of water vapor in kilograms per kilogram of air may be denoted by x, where

$$x = \frac{G_D}{G_L} = \frac{2.153}{3.460} \times \frac{\varphi h'}{h - \varphi h'} = 0.622 \frac{\varphi h'}{h - \varphi h'} \quad [5]$$

and the total weight of the mixture is $G = 1 + x$. The volume of such a mixture is

$$V = \frac{2.153\, T}{h - \varphi h'} \quad [6]$$

and the partial volume occupied by the water vapor is

$$r_D = \frac{\varphi h'}{h} = \frac{x}{0.622 + x} \quad [7]$$

In technical calculations regarding water vapor-air mixtures one needs above all, in addition to a knowledge of the relations between pressures, temperatures and volume, a knowledge of their heat content i. In the case of perfect gases the heat content (assuming that within the narrow range of temperature dealt with here the specific heat c_p is constant) is

$$i = c_p t + C$$

where the constant C is arbitrary. For air it is zero, which means that the heat content of the mixture is calculated on the basis of air at 0 deg. cent. so that $c_p = 0.24$.

For water vapor within the corresponding range of temperature $c_p = 0.46$. It is, however, of advantage to refer in calculating the heat content of water vapor, not to vapor at 0 deg. cent. but to water at that temperature; the constant heat of evaporation at 0 deg. cent. is then 595 kg. cal., and

$$i_L = 0.24\, t \text{ and } i_D = 595 + 0.46\, t$$

and for the heat content of a mixture containing 1 kg. of air

$$i = i_L + x i_D = 0.24\, t + x\,(595 + 0.46\, t) \quad [8]$$

$$i = 0.24\, t + 0.622 \frac{\varphi h'}{h - \varphi h'}\,(595 + 0.46\, t) \quad [8a]$$

[1] Dresden, Germany.

$$i = 0.24\,t + \frac{\varphi h'}{h - \varphi h'}\,(370 + 0.286\,t) \ldots\ldots\ldots [8b]$$

It is important to note that these formulas give also the heat content of 1 kg. of air plus x kg. of water vapor plus any desired amount of water at 0 deg. cent.

In practice one has most frequently to deal with variations of state which occur at constant total pressure, this pressure being generally the same as the external pressure. In such cases the solution of practical problems may be materially simplified by graphic methods. As the state of a water vapor-air mixture containing 1 kg. of air and a given constant total pressure h is determined by two out of four variables, t, i, x, and φ, it becomes possible to select two of these families of curves for constant values, treating the other two as variables. According to the procedure suggested by O. H. Mueller, t and i are generally chosen for coördinates of the diagram, and curves are plotted for equal values of x and of φ, the former being straight lines.

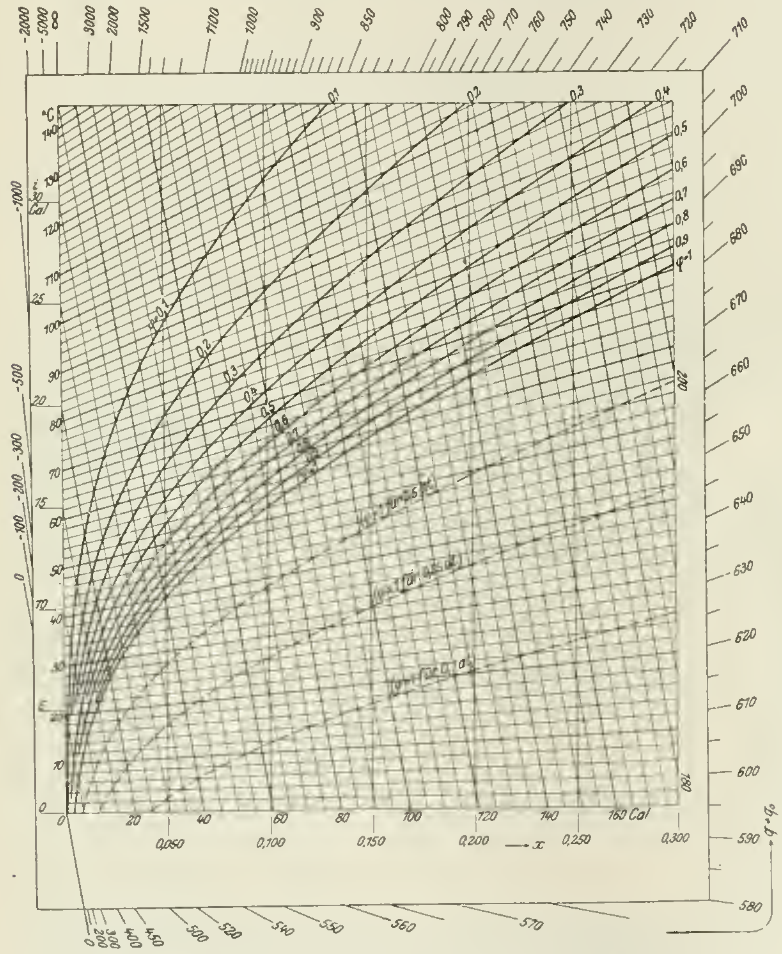

Fig. 1 Mollier Diagram for Water Vapor-Air Mixtures

The author suggests another procedure in which i and x are used as coördinates (Fig. 1). This gives a diagram which affords solutions of all the problems solvable by the i-t diagram, as well as of those that cannot be handled by the latter. For the best results the author recommends the use of coördinates at acute angles to each other. Favorable conditions are secured by making the 0-deg. line passing through the origin horizontal. (The isotherms are straight lines in accordance with Equation [8].) The diagram is then used in the following manner. First, Equation [8] is written in the form

$$i = (0.24 + 0.46\,x)\,t + 595\,x \ldots\ldots\ldots\ldots\ldots [8c]$$

where the first member i' represents the heat constant of the mixture referred to air and water vapor at 0 deg., and the second member is the heat of evaporation of the vapor x at 0 deg. Next x and i' are selected as abscissas and ordinates in a rectangular system in which $i' = (0.24 + 0.46\,x)\,t$.

The isotherms are straight lines cutting off equal sections on the ordinates for equal differences of temperature. The line $t = 0$ coincides with the axis of abscissas. The lines for constant degrees of saturation can be easily plotted in accordance with Equation [5]. Both groups of lines remain unaffected in passing to the acute-angle system of coördinates with i and x as coördinates, which is accomplished by plotting $595\,x$ from the available axis of abscissas downward. The straight line thus obtained is the ultimate axis of abscissas and indicates the direction of lines of constant heat content.

The diagram of Fig. 1 is plotted for a pressure of 735.5 mm. = 1 atmos., but may be used without introducing material errors for other air pressures in close proximity thereto. The isotherms are not affected by the fact that a different total pressure is used as the basis of the diagram. The behavior of curves of equal degrees of saturation is given in this case by Equation [5] which can be written in the following form:

$$x = 0.622\,\frac{\left(\frac{735.5}{h}\,\varphi\right)h'}{735.5 - \left(\frac{735.5}{h}\,\varphi\right)h'} = 0.622\,\frac{\left(\frac{\varphi}{p}\right)h'}{735.5 - \left(\frac{\varphi}{p}\right)h'}$$

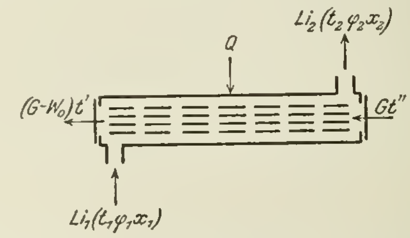

Fig. 2 Diagrammatic Sketch of a Continuous-Process Drier

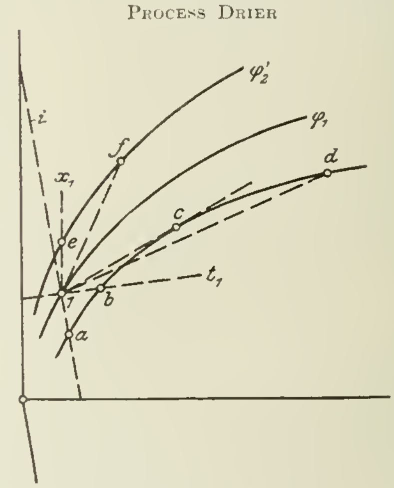

Fig. 3 Curves Used in Computing the Heat Balance of the Drier Shown in Fig. 2

where h is in millimeters and p in atmospheres expresses the new total pressure. It would appear from this that the family of φ-lines is not affected either, though the value of φ appertaining to any one of them changes with pressure. A line which represents the value of φ at a pressure of 735.5 mm. or 1 atmos. corresponds at h mm. or p atmos. to the degree of saturation $\frac{h}{735.5}\,\varphi$ or to $p\varphi$. In the diagram of Fig. 1 are plotted a few lines of complete saturation for other pressures.

The diagram may also be used for changes of state where the vapor content of the air remains constant. In this case x is constant and the change of state is indicated by drawing a parallel to the axis of the ordinates. For this purpose the new diagram has the advantage as compared with the i-t diagram that the heat which has to be either supplied or abstracted as the case may be, is indicated simply by the distance between the initial and end points of the change of state. To find the dewpoint, all that is necessary is to move parallel to the axis of the ordinates up to the point of intersection with the curve $\varphi = 1$ and read off the corresponding temperature.

As a rule, in changes of state of water vapor-air mixtures it is the vapor content x of the air that varies. In such cases one has to consider not only the gaseous constituents but also a certain amount of liquid water which either arises through condensation or disappears through evaporation; it is expressed in a change of state from 1 to 2 of 1 kg. of air by $x_2 - x_1$. The variation of the heat content F, $i_2 - i_1$, given by the diagram or by Equation [8], represents in this case not the heat which has to be supplied or abstracted during the change of state, but an amount smaller or greater than that by $(x_2 - x_1)\, t_0$, where t_0 is the initial or final temperature of the evaporated or condensed water. This is possible, because as has been stated above the present diagram and likewise Equation [8] give the heat content of a water vapor-air mixture with a content of 1 kg. of air plus any amount of liquid water at 0 deg. cent. Hence

$$Q_{1,2} = i_2 - i_1 - (x_2 - x_1)\, t_0$$

Application of the Diagram

The author gives three examples of the application of his diagram to the solution of practical problems: namely, the establishment of the heat balance of a drier, drying with preheated air, and the establishment of the heat balance of a return cooling plant. Because of lack of space only the first of the three can be reported here.

Fig. 2 shows a continuous-process drier. G kg. of wet material are delivered to the drier per hour at the temperature t'' and leave it at the temperature t' weighing $G - W_0$ kg., where W_0 is the weight of the water abstracted from the goods in the drier in the unit of time. The specific heat of the dried goods in the final state is c. The physical characteristics of the handling devices are taken care of by the values of Gc. The drier receives per hr. L kg. of air having the temperature t_1, vapor content x_1, degree of saturation φ_1, and heat content i_1; in the same period the same amount of air (at t_2, φ_2, x_2, and i_2) leaves from the drier. Furthermore the drier receives per hr. an amount of heat equal to Q kg-cal., it being immaterial how this heat is introduced, and loses through radiation and convection Q_V kg-cal. per hr. The heat balance of the drier is therefore

$$Q = L\,(i_2 - i_1) + (G - W_0)\, c\,(t' - t'') - W_0 t'' + Q_V \ldots . [9]$$

This may be expressed in terms of kilograms of water extracted from the goods; if Q/W_0 be replaced by q and L/W_0 by l, then

$$q = l\,(i_2 - i_1) - \left[t'' - \left(\frac{G}{W_0} - 1\right) c\,(t' - t'') - \frac{Q_V}{W_0}\right]. \quad [9a]$$

The bracketed portion of the equation may be designated by q_0; and its value as compared with $l\,(i_2 - i_1)$ is in many cases so small that it may be neglected entirely. It is only where G/W_0 is very large, as for example, in the drying of vegetables, that q_0 may attain considerable negative values.

The water W_0 abstracted from the goods leaves the drier in the form of vapor mixed with the air and raises the initial vapor content x_1 of the latter to x_2. Hence

$$W_0 = L\,(x_2 - x_1) \text{ or } l\,(x_2 - x_1) = 1 \ldots\ldots\ldots [10]$$

and by combining Equations [9a] and [10],

$$q + q_0 = \frac{i_2 - i_1}{x_2 - x_1} \ldots\ldots\ldots\ldots\ldots\ldots [11]$$

For purposes of numerical calculation values from Equations [8] and [8a] may be introduced into Equation [11], giving

$$q + q_0 = 595 + (0.24 + 0.46\, x_1)\, \frac{t_2 - t_1}{x_2 - x_1} + 0.46\, t_2 \ldots [11a]$$

$$q + q_C = 595 + \frac{0.386 + 0.46\,\dfrac{\varphi_1 h'_1}{h - \varphi_1 h'_1}}{\dfrac{\varphi_2 h_2}{h - \varphi_2 h'_1} - \dfrac{\varphi_1 h'_1}{h - \varphi_1 h'_1}}\,(t_2 - t_1) + 0.46 t_2 \ldots [11b]$$

The last equation gives the heat consumption of a drier as a function of temperatures and degrees of saturation of the incoming and outgoing air.

The consideration of the relations affecting heat consumption and their calculation is greatly facilitated by the use of the i-x diagram. One may start from the simple Equation [11] which shows that the value of $q + q_0$ is given simply by the angle of inclination of the line connecting the points 1 and 2, which corresponds to the state of the air at the entrance to and exit from the drier, and, in turn, is given by the temperatures t_1, t_2 and degrees of saturation φ_1, φ_2. In order to facilitate still further the determination of q there is given on the edge of the diagram a scale for the values of i/x. All that is necessary, therefore, is to draw through the origin a line parallel to the line connecting 1 and 2, and this line will cut off on the scale on the edge of the diagram the value $q + q_0$. Since q is always of the order of magnitude of the heat of vaporization, q_0 may be often neglected entirely.

The specific air consumption, which, according to Equation [10], is $l = \dfrac{1}{x_2 - x_1}$, is given by the reciprocal value of the horizontal distance between points 1 and 2. This distance itself represents the amount of water which may be dried out by the flow of 1 kg. of air.

Drying is possible when $x_2 > x_1$. If no heat is supplied, $q = 0$, and we have the case of natural drying. Then must $\varphi_1 < \varphi_2$, and for $q_0 = 0$, $i_1 = i_2$ and $t_2 < t_1$, and the consumption of air is very large. This case is represented in Fig. 3 by the distance 1-a.

If we assume that the initial state of the air and φ_2 are constant and that t_2 is gradually rising, we shall find that the heat consumption is increasing but the air consumption falls off. For $t_2 = t_1$, or 1-b, it will be found that $q + q_0 = 595 + 0.46\, t_1$. In other words, we are dealing here with the heat content of steam at the temperature t_1. However, q may increase only up to a certain maximum value, which is reached when the straight line 1-c drawn through the origin intersects with the φ_2-curve. With a further increase of t_2, $q - q_0$ falls off again (line 1-d) until for $l_1 = 0$ we have $x_2 = \infty$, which in the case of pure evaporation gives $q + q_0 = 595 + 0.46 t_2 = 640$. If $\varphi_1 > \varphi_2$ it begins to become possible to produce drying, but only at a temperature of $t_2 > t_1$ (line 1-e, Fig. 3), when $l = \infty$ and $q = \infty$. As the temperature t_2 rises, q falls off gradually (line 1-f) and the former maximum value disappears. (*Zeitschrift des Vereines Deutscher Ingenieure*, vol. 67, no. 36, Sept. 8, 1923, pp. 869–872, 5 figs., *epA*)

Short Abstracts of the Month

ENGINEERING MATERIALS

Record of Interior Temperatures in Concrete. Data of an investigation which is being carried on by Mr. J. B. Henley on a large reinforced-concrete arch being built by the Big Four Railroad over the Miami river at Sidney, Ohio.

Soon after the forms were removed from one of the piers, cracks were noted at a number of places on the face of the pier. After considering all the conditions, the conclusion was reached that the trouble was caused by a more rapid reduction of the temperature of the surface of the pier than of that part slightly below the surface. In other words, it was believed to be due to rapid surface radiation, which necessarily presupposed comparatively higher interior temperatures than were known to exist.

An investigation was therefore determined upon on a mass of freshly deposited concrete and proper arrangements were made to place several thermometers at various points in a block.

The data of these observations are presented in the original article in the form of temperature-record diagrams. In all cases it was found that there was the same rapid rise in temperature, the same curve of initial fall, the same relative lower temperature, and that substantially a period of two months elapsed before the effect of external temperatures was observed. (*Railway Review*, vol. 73, no. 14, Oct. 6, 1923, pp. 481–484, 4 figs., *e*)

The Significance of Tool Temperatures as a Function of the Cutting Resistance of Metals, H. A. Schwartz[1] and W. W. Flagle.[2] The authors describe an instrument for recording the

[1] Mem. A.S.M.E.

[2] Engineer of Tests, Research Dept., The National Malleable Castings Co., Cleveland, Ohio.

changes of temperature of a drill or other cutting tool in action. It is believed that the life of a given tool is a function of its working temperature, and hence that the temperatures reached under given cutting conditions in varying materials are an indication of their machinability or cutting hardness.

Data covering typical ferrous alloys of commerce are given. Some relations between energy per cubic inch of metal removed, temperature, and rate of removal of metal are shown which suggest the utility of the pyrometer in lieu of a tool dynamometer. The further study of the behavior of tool steels at various temperatures is suggested. (Paper presented before the *American Society for Testing Materials* at Annual Meeting, Atlantic City, N. J., June, 1923. Abstracted from preprint, 14 pp., 7 figs., *e*)

Resistance of Manganese Bronze, Duralumin, and Electron Metal to Alternating Stresses, R. R. Moore.[1] This paper gives the results of an investigation made by the Engineering Division of the Air Service at McCook Field, Dayton, Ohio, to determine the endurance limit of duralumin bar stock as rolled, annealed, and tempered. Similar investigations on manganese bronze and electron metal are included. Tests were made on rotating-beam machines of the same type as used in the fatigue investigation at the University of Illinois and on the same type of specimen.

In addition to having established an endurance limit for duralumin, some other important points covered are:

1 Evidence that the endurance limit of non-ferrous metals cannot be determined by applying 10,000,000 repetitions of stresses, as is the case with most steels. This is borne out by tests in which failures have been obtained at 30, 50, 80, and even 100 million repetitions of stress.

2 Results of long-time tests, that is, 200 to 400 million repetitions of stress

3 Polishing of specimens at the critical section

4 Difficulties encountered in adapting this type of machine and specimen (which were primarily designed for steel) to light aluminum alloys. (Paper presented before the *American Society for Testing Materials* at Annual Meeting, Atlantic City, N. J., June, 1923. Abstracted from preprint, 17 pp., 8 figs., 2 tables, *c*)

FOUNDRY (See Railroad Engineering)

FUELS AND FIRING (See also Testing and Measurements, Motor-Car Engineering)

Geissinger Automatic Temperature Control for Oil-Fired Furnaces. Description of a system devised by H. G. Geissinger, of Detroit, Mich. The illustration in the article shows a unit built into pipe lines which feed a Rockwell furnace.

In this control system electricity is used as a motive force because safety against overheating is assured if the power supply fails. The principal part of the equipment consists of a center casting which houses a single two-pole strong magnet. This is energized as long as the indication of the pyrometer is below normal. The magnetic flux attracts the armatures which are fastened to the valves and holds them wide open. As soon as the indication of the pyrometer exceeds the normal value, the current flowing through the magnet coil is interrupted and both fuel and air valves are returned to the almost closed position by springs. The control of the relay which switches the power on and off the solonoid can be affected by any depresser-bar pyrometer.

If one of the two valves moves harder than the other one, no harm is done, because the freely moving valve is attracted first and by its attachment to the magnet greatly increases the magnetic flux, thereby vastly augmenting its strength. The sticking valve is moved without fail by this strong force.

Since in this system both fuel and air are controlled by valves, it may under certain conditions be used to control not only furnace temperature but furnace atmosphere. The original article shows the piping diagram of this system for fuel-fired furnaces and the wiring diagram for the fuel control system. (*Fuels and Furnaces*, vol. 1, no. 6, Oct., 1923, pp. 437–439, 4 figs., *d*)

[1] Chief, Physical Testing Branch, Engineering Div., U. S. Air Service, McCook Field, Dayton, Ohio.

HYDRAULIC ENGINEERING

Weir Flow

Weir Flow, Dempster Smith and Dr. Wm. J. Walker.[1] In a previous paper (Proc. Inst. M.E., 1923, p. 23) the authors investigated orifice flow with the object of obtaining a formula based on physical considerations. In that paper it was found that the chief factor governing variations in the coefficient of discharge C_d is adhesion and not friction. With low heads and small orifice dimensions adhesion plays a very effective part, and it is perhaps the neglect of this factor which would explain certain difficulties occurring in hydraulic experimental work at low velocities of flow and with small-dimension channels.

In setting out upon the experimental work on weir flow the object held in view was to render by the measurement of as many variables as necessary an analysis which would result in the derivation of a sufficiently general formula capable of application to limited cases. Because of lack of space only the main results can be given here.

Rectangular Weirs. As regards the coefficient of contraction C_c, it would appear that for each width of weir the tendency is for constancy of contraction for all heads. With this in view it was decided to consider C_d (coefficient of discharge) in Formula [1]

$$Q = \frac{2}{3} C_d b\sqrt{2g}\left(h^{\frac{3}{2}} - h_1^{\frac{3}{2}}\right) \quad \ldots\ldots\ldots\ldots\ [1]$$

as constant for each width of weir.

The relation between h and h_1 (Fig. 1) was determined next and found to be such that it could be represented by $h_1 = kh^n$, where

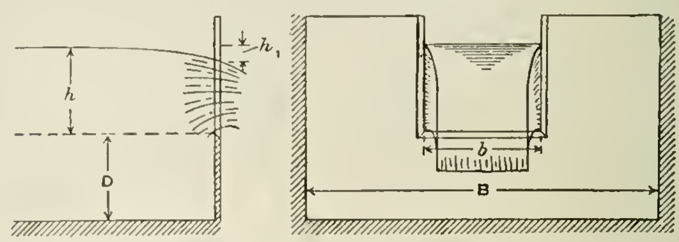

Fig. 1 Rectangular Weir

n depended upon the ratios b/B and $h/(h + D)$ (Fig. 1). Eventually k was chosen as 0.15 and n as

$$\sqrt{\frac{b}{B}} + \sqrt{\frac{h}{h+D}}$$

The relation between C_c and width of weir was expressed by the formula

$$C_c = \frac{1.08\,\pi}{\pi + 2\left(1 - \frac{b}{B}\right)}$$

which allows for the diversion of the stream lines due to the proximity of the walls of the approach channel. This was found to fit the results fairly closely.

The general formula [1] now becomes

$$Q_t = \frac{2}{3} C_c C_v b\sqrt{2g}\left(h^{\frac{3}{2}} - 0.15\, h^{\frac{3n}{2}}\right)$$

where C_c and n have the values indicated above and C_v is taken equal to 0.965. The necessity for the factor 1.08 in the formula for C_c is considered to be due to the fact that in weir flow a free surface exists which does not hold in jet flow, contraction consequently not being so complete in the former as in the latter type of flow. The formula, then, as finally adopted is

$$Q_t = \frac{2}{3} C_d b\sqrt{2g}\left(h^{\frac{3}{2}} - 0.15\, h^{\frac{3n}{2}}\right)$$

If measurements are made in inches this may be written as

$$Q_t = \frac{60.3\ b}{\pi + 2\left(1 - \frac{b}{B}\right)}\left(h^{\frac{3}{2}} - 0.15\, h^{\frac{3n}{2}}\right) \text{ cu. in. per sec.}$$

[1] College of Technology, Manchester, England.

If in feet,

$$Q_t + \frac{17.4\,b}{\pi + 2\left(1 - \frac{b}{B}\right)}\left(h^{\frac{3}{2}} - 0.15\,h^{\frac{3n}{2}}\right) \text{ cu. ft. per sec.}$$

A peculiar feature about this formula is that it indicates, for a given head, that the discharge is increased by narrowing the approach channel, but diminished by diminishing the depth D of the channel bed below the sill of the weir.

The authors derive similar formulas for the right-angled notch. (*Proceedings of the Institution of Mechanical Engineers*, no. 4, June, 1923, pp. 819–834, 8 figs., *tA*)

INTERNAL-COMBUSTION ENGINEERING (See Motor-Car Engineering)

MACHINE PARTS AND DESIGN

Falk-Bibby Flexible Couplings

Falk-Bibby Flexible Couplings. Description of a new coupling, Fig. 2, used for the transmission of power between shafts which may be either parallel or in angular misalignment. The coupling consists of two flanged steel disks (one keyed to each shaft), a tempered steel spring in segments, forming a continuous cylindrical grid, and a shell. On the outsides of the flanges are pitched cross-grooves in which the spring is placed. The spring is the flexible member and its shape, and that of the grooves, forms the characteristic feature of the coupling. The grooves in the disk widen inward toward each other, so that the spring fits closely in them only at their outer ends. This widening of the grooves is in

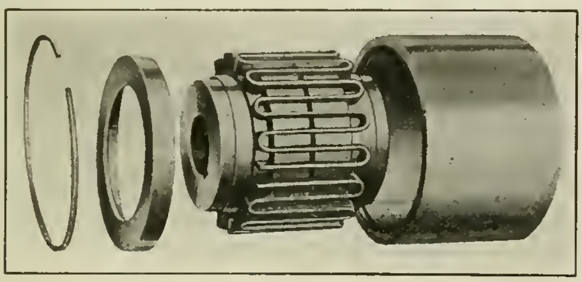

Fig. 2 Falk-Bibby Coupling

the form of an arc of definite radius and is produced by special machines used for the manufacture of these couplings. The radius of the arc bears a definite relationship to the thickness of the spring bars and is designed so that when each bar is bent around this radius the stress in the spring cannot exceed a fixed safe value. Under light and normal loads there is a long free span of spring between the points of support on the two flanges, which allows for considerable flexibility, but under heavy overloads the spring members become supported along the sides of the grooves, thereby automatically shortening without increasing the stress.

Under very extreme overloads the springs are supported at their inner ends and are then in shear and capable of resisting many times the load for which the coupling is designed.

The flexibility of the springs is always properly proportioned to the load. Under a light load each bar or element is flexed between points separated by the maximum distance. As the load increases the springs wrap themselves around the walls of the grooves, with their inwardly flaring construction, and the proper curving of these grooves makes it possible for the increasing load to shorten the effective span of each spring bar, thus causing it to offer greater resistance to bending without increase of stress. A high degree of torsional flexibility, with greater resistance to increased torque, is thereby produced.

All the working parts of the coupling are enclosed in a floating shell which provides space for the packing of lubricant. The shafts are aligned as easily as with flange couplings, and disconnection is accomplished expeditiously by simply releasing the shell and removing the springs around the periphery of the flanges. (Abstracted from a company publication, Bulletin No. 33, 6 pp., illustrated, *d*)

MACHINE SHOP (See also Engineering Materials)

Double Tables on Milling Machines

Increasing Production Milling by Doubling Tables, Frank H. Mayoh, Mem. A.S.M.E. An article describing means of converting a regular vertical or horizontal milling machine, having one table, into a machine of increased capacity. To this end, as shown in Fig. 3, the machine is equipped with two traveling tables mounted on a special saddle, and regular knee construction with some modifications is used.

By means of this arrangement continuous milling can be accomplished, as an operator loads work on one table while the other table is passing under the milling cutter. He need not wait for one table to complete its cut before starting the next, but may start it as soon as he is ready or has the work in place, thus performing even more work than is performed on a continuous rotary-table machine, and with fewer fixtures and a greater range of work.

This necessitates two gangs of cutters on the arbor in the case of a horizontal machine, or in the case of a vertical machine two vertical spindles with cutters or a surface mill of a diameter which will cover work on both tables.

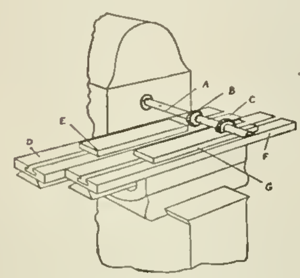

Fig. 3 Knee Type of Milling Machine with Two Tables

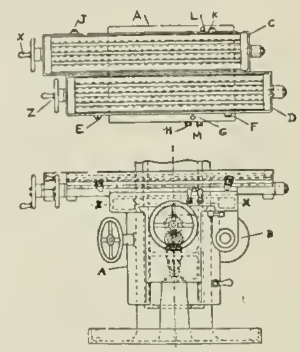

Fig. 4 Arrangement of Two Tables for Milling

In Fig. 3 the milling spindle is indicated at A. This has two cutters mounted thereon, B and C. A table D, having work indicated as E, is fed under the cutter B, while at the same time a table F, having work G mounted thereon, is fed under the cutter C. Both of these tables are fed at once, intermittently, as fast as the cut can be completed and the operator can load the fixtures on the tables. It is not necessary to wait for both tables to be loaded, as they can be fed one before the other as illustrated.

Two tables somewhat narrower than those regularly employed can be fitted on a machine of normal size of either the light-weight, medium-weight, or heavy class.

Fig. 4 is a plan view and front elevation of a pair of tables mounted on the knee of a milling machine, showing the general arrangement and method of operation. In these views the knee of the machine is indicated at A, and a train of gears in a case at B drive the two tables C and D through intermediate gearing in the knee. Table stops E and F, in combination with a plunger L and lever M, control the feeding of table C.

The article describes and illustrates several set-ups that can be used with this arrangement, in particular a case of straddle milling and continuous milling. It shows also that this arrangement is adapted to rotary work and that the feed may be arranged to work in opposite directions. (*Canadian Machinery*, vol. 30, no. 13, Sept. 27, 1923, pp. 14–17 and 32, 13 figs., *dp*)

MACHINE TOOLS

A New Herringbone-Gear Planer

A New Herringbone-Gear Planer, N. Leerberg. Description of a new design in which two tools cut simultaneously and move in a helical path, the work being held stationary during cutting to give stability.

In cutting gears with a pitch greater than 1 D.P. the usual methods are claimed to have drawbacks. The cutting surface of the tools becomes so great that it is difficult to obtain sufficient rigidity for

efficient operation. It is necessary to machine the teeth from the solid blank, requiring the removal of great quantities of metal, and also giving a metal not as close-grained as when the teeth are blocked out in casting. It is for such work on coarse pitches that the planing process is best adapted.

In the earlier herringbone-gear planers the gear blank was made to rotate as the tool advanced along the face of the gear, but the spring in the gear blank when the latter was much over 6 ft. in diameter made it impossible to make good time on such a machine. About seven years ago a machine was developed in which the gear blank was clamped rigidly while the tool passed along an approximate helical path. The machine described here is a further development of this.

The principle of the machine is as indicated diagrammatically in Fig. 5, and the motion is the resultant of the longitudinal motion

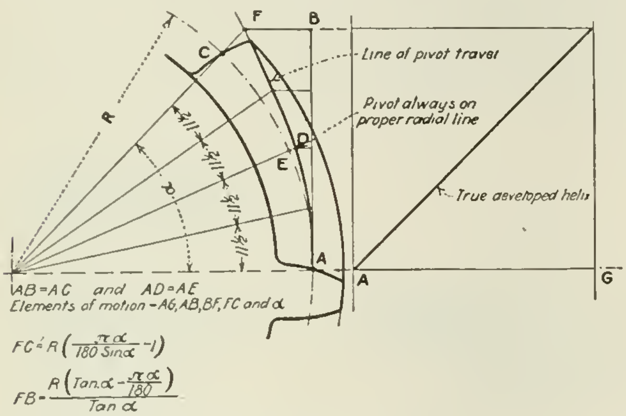

Fig. 5 Diagram Showing How Helical Motion of Cutting Tool in the Herringbone-Gear Planer is Obtained

AG, vertical motion *AB*, transverse motion *BF*, radial motion *FC*, and angular motion α. The primary motion is therefore the development of a helix in a vertical plane tangent to the pitch cylinder. But this development is constantly being folded into the cylindrical pitch blank as follows: The pivot point is moved transversely the distance *BF* until it falls on the proper radial line. The tool is then swung radially around a pivot following the line *AF*, and thereafter moved along the radial line until the cutting point falls at the pitch line. All these motions are simultaneous.

Mechanically these motions are produced in a machine shown in drawings in the original article. The machine consists mainly of two sole plates carrying the base plate on which are mounted two columns. These columns carry two vertical slides having pivots, and the planer rail is supported by these pivots as well as by worm drives.

The tool-head carriers slide simultaneously toward the center of the gear face during the cutting stroke. The drives and action of the specific parts are described and illustrated in the original article. (*American Machinist*, vol. 59, no. 15, Oct. 11, 1923, pp. 561–563, 3 figs., *d*)

Nibbling Machines. Description of two nibbling machines made by Andrew C. Campbell, Inc., Bridgeport, Conn.

The principle of operation of these machines is somewhat on the order of a combination slotting and punching action. In the first machine sheet stock of whatever material, including steel, brass, aluminum, bakelite, fiber, etc., may be quickly cut to any desired outline of regular or irregular contour through the use of lines scribed on the sheet, or the work may be guided by a templet superimposed on it, the amount of feed being governed by a stop which is a part of the cutting tool or punch.

The machines were shown at the Machine Tool Exhibition held recently at Yale University, where one of them was employed on roughing out Brown and Sharpe automatic screw-machine cams.

One of these machines produced a five-lobe cam from 3/8-in. stock, ready for filing and hardening, in 1 min. 50 sec. It was also used in making stripper plates. The machine is adaptable for the production of a limited number of duplicate parts.

Rapid action, quick adjustment, ease of operation, simplicity of parts, and low upkeep of tools are features claimed for these machines. (*The Iron Age*, vol. 112, no. 15, Oct. 11, 1923, p. 964, 2 figs., *d*)

MEASURING APPARATUS (See Hydraulic Engineering)

MEASURING INSTRUMENTS (See Testing and Measurements)

MECHANICS

Stresses in Pipes, Prof. Gilbert Cook. The paper deals with the design of pipe lines in large hydroelectric installations working under high heads. For a given discharge and head at the power station, considerable economy in material can be effected by increasing the size and reducing the number of the pipes. In the plain welded pipe a limit of size is imposed by the maximum thickness which can be welded satisfactorily, and recourse has been had to a system of reinforcement by means of steel rings shrunk on at intervals. Interest arises as to the method by which the strength of these pipes may be estimated. The investigation dealt with by the author has several points of interest, among them the question as to the conditions under which a reinforced pipe can be made lighter than a plain pipe. Some unexpected conclusions have been reached regarding the relation between the spacing of the ring reinforcement and its effectiveness. The author has investigated the stresses in the case of a reinforced pipe in the pipe line of the Los Angeles power station. The internal diameter of the pipe is 80 in. and the thickness 0.63 in. The reinforcing rings are 4.45 in. wide by 1.575 in. thick, and are spaced 11.05 in. center to center, leaving an unsupported length of pipe equal to 6.60 in. The working pressure is given as 278 lb. per sq. in. It is shown that the possibility of allowing a higher working stress in the rings than would be safe for the pipe, enables a reinforced pipe to be made lighter than a plain pipe, provided that the rings are sufficiently close together. Details are given of a calculation on the Los Angeles pipe, assuming a stress of 10 tons per sq. in. for the rings and 6 tons for the pipe, which shows that the spacing of the rings must be less than 12 in. clear to obtain a lighter pipe. (Paper before the British Association, abstracted through *The Engineer*, vol. 136, no. 3535, Sept. 28, 1923, p. 333, *ep*)

MOTOR-CAR ENGINEERING

Supercharger in European Grand Prix Race, W. F. Bradley. The triumph of the supercharged engine is said to be the outstanding technical feature of the European Grand Prix race, Sept. 9, 1923, which resulted in a victory for an eight-cylinder Fiat at an average of 91.03 m.p.h. The Fiat Company admitted that its success was due entirely to the use of the supercharger.

As a result of its racing experience the Fiat Company has fitted superchargers to its new 500-hp. aviation engines built for a French competition and is also using superchargers on marine engines. No details as to construction of the Fiat supercharger are given in the article. (*Automotive Industries*, vol. 49, no. 14, Oct. 4, 1923, pp. 676–677, 5 figs., *g*)

Acetylene-Driven Motor Cars. The question of the use of acetylene as a motor fuel came up soon after the armistice, in view of the scarcity and high cost of gasoline, benzol, and the like in Germany. Some tests were made, but without any especially encouraging results until Engr. Bullermann, of Hanover, succeeded in driving an automobile by using a mixture of acetylene gas with 10 to 20 per cent of liquid fuel.

The Swiss Acetylene Verein Zurich, which is interested in all applications of acetylene, published several scientific papers on this subject, among them a book by Prof. C. F. Keel (in German) under the title Acetylene in Automobile Operation. The present article is apparently based on this publication.

There are several ways (generally well known) by which acetylene can be produced. Its mixing with air may be carried out in mixing valves. Acetylene-air mixtures have to be diluted by means of an adjustable nozzle with a water spray. The power delivered

by an acetylene-fed engine may be regulated by varying either the total amount of mixture or the acetylene content only, as acetylene-air mixtures are explosive over a wide range of ratios of the two gases.

The original article describes a number of systems proposed for driving motor cars by acetylene, none of which has attained any extensive use. In the Bullermann system, which is described in detail, the acetylene gas is mixed with 10 to 20 per cent of heavy oil and an automatic mixing valve is provided.

In Sweden the Lux Company is said to have developed a process for using a mixture of benzol and acetylene dissolved in sulphite spirits.

Engr. N. H. Rustige proposes another method in which from 5 to 6 kg. of calcium carbide are dissolved in 100 kg. of 92-deg. sulphite spirits and the mixture is fed into an ordinary carburetor.

The article gives no information as to the important question of the state of the engine cylinders after a couple of thousands of miles of running on any of these fuels. (*Motor und Auto*, vol. 20, no. 17, Sept. 10, 1923, pp. 147–149, *gd*)

Hydraulic Four-Wheel Brakes for Motor Cars

Hydraulic Four-Wheel Brakes for Automotive Vehicles, Malcolm Loughead.[1] Description of a hydraulic four-wheel brake system and a statement of requirements in four-wheel brake design. In this system pressure is built up in a cylinder mounted on the transmission case near the fulcrum of the brake pedal. The system consists of a master cylinder, piping, and reservoir tank. Mounted rigidly on the dust shield or anchor bracket of each one of the four wheels is a brake-band-actuating cylinder that is connected to the pressure line on the chassis frame by a suitable length of seven-ply rubber hose capable of resisting a pressure of 2000 to 2500 lb. per sq. in. before bursting.

The hose has a close-wound coil spring inserted while the hose is under a pressure of 1200 to 1400 lb. per sq. in. There is practically no expansion loss up to a pressure of 1000 lb. per sq. in., this being a very important factor with hydraulic brakes because two movements, those of steering and of spring action, must be provided for by using flexible connections. An expansion loss in the hydraulic system causes a lessening of the amount of pedal travel; to compensate for this loss it is necessary to reduce the amount of pedal leverage, and this would require a greater pedal pressure.

Each of the individual brake-actuating cylinders on the four brake supports contains a pair of opposed pistons, one at either end of the cylinder. See Fig. 6. These pistons act against two levers that are in turn connected to the brake-band ends, the brake bands being of the external contracting type. Liquid is admitted to these brake-actuating cylinders between their opposed pistons through an opening at the cylinder centers. When the brake pedal is depressed, the opposed pistons in each cylinder are forced apart by the hydraulic pressure set up in the system by the master cylinder; one end of each of the levers in each brake-actuating cylinder bears on the head of one of its opposed pistons and the other end exerts a pull on the brake-band end, drawing it tangent to the drum. Smooth brake action is assured by drawing the brake-band ends in a line tangent to the brake drum and not allowing the ends to "snub." Since the opposed pistons are forced apart by hydraulic pressure, it follows that the pressure on both pistons in all four brake-actuating cylinders must be equal. The brake-actuating-cylinder group assembly is shown in detail in Fig. 6.

A mixture of alcohol and glycerine, 40 per cent alcohol and 60 per cent glycerine, constitutes the liquid used in the hydraulic braking system. Any leakage of liquid from the system is compensated for from a small reservoir mounted on the dash that replenishes the master cylinder automatically. When the master-cylinder piston is in the "off" position, it uncovers several small port holes, each about 0.02 in. in diameter, that communicate directly with the reservoir. This allows a free flow of liquid from the tank to the master cylinder and replenishes any loss of liquid that may occur during the application of the brakes. If there is any loss of liquid, it is very slight; in fact, cars have been run for several months with a closed line and have lost practically none of the fluid. Rawhide is used to pack the pistons and prevent any leakage of the fluid from the hydraulic cylinders.

[1] Chief Engineer, Hydraulic Brake Co., Detroit, Mich.

From this the author proceeds to discuss the six essential factors of design of a four-wheel braking system. These factors are: (1)

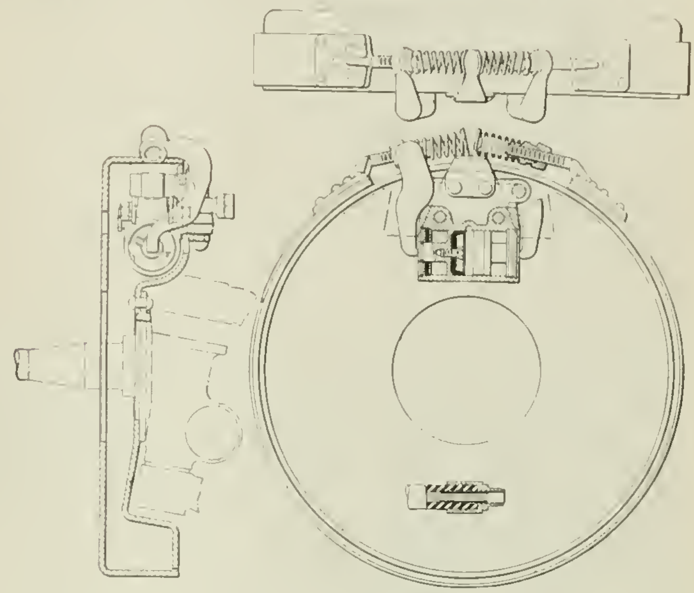

Fig. 6 Wheel Cylinder Group Assembly with a Section of the Hose End Shown in the Lower Section

Reliability, (2) equalization, (3) stopping ability, (4) control, (5) simple adjustments and minimized service requirements, (6) wear and replacement of parts. (*The Journal of the Society of Automotive Engineers*, vol. 13, no. 4, October, 1923, original paper pp. 313–316 and discussion pp. 316–321, 3 figs., *d*)

ORDNANCE

The German Long-Range Gun, H. W. Miller. The article is based on material previously published, among which is an article by Lt.-Col. H. W. Miller, U. S. A., published in Mechanical Engineering, February, 1920, pp. 89–100; some of the material, however, is not generally accessible.

The most interesting part of the article is the relationship between height and length of trajectory for the long-distance guns. It would appear the German calculations indicated that if a projectile could be given an initial velocity of approximately 1600 m. (5250 ft.) per sec., it would traverse a distance of 72 miles if started at an elevation of 55 deg., because during most of its period of travel it would be passing through atmosphere of such rarity as to oppose relatively little resistance to its flights, and cross-currents of air would have relatively little tendency to cause the projectile to drift off its theoretical path. According to information secured by the American Army Commission on its visit to the Skoda Works at Pilsen in May, 1919, the German investigations showed the following relation between muzzle velocity and elevation for maximum range:

Muzzle Velocity, Meters per sec.	Muzzle Velocity, Ft. per sec.	Elevation for maximum range
750	2460	42 deg.
850	2790	50 deg.
900	2950	52 deg.
1600	5250	55 deg.

The results of calculations also indicated that for a gun having a range of, say, 100 km., the economic diameter was about 8 in., the weight of the projectile about 264 lb., the powder charge 525 lb., and the powder chamber about 10 ft. long and cylindrical to receive the metal case in which the charge would be contained. To secure the velocity of 1600 meters (5250 ft.) per second the gun would have to be at least 140 calibers long. (*Army Ordnance*, vol. 4, no. 20, Sept.-Oct., 1923, pp. 98–100 and 122–123; to be continued, *d*)

POWER-PLANT ENGINEERING (See also Testing and Measurements)

Steam Turbines—Last-Stage Expansion

Development of the Steam Turbine, Stanley S. Cook.[1] Lecture delivered before the Royal Society of Arts, May 7, 1923, dealing in the first part with marine turbines and in the second with matters pertaining to both marine and land turbines.

In the first part a good deal of attention is paid to the subject of gearing and thrust blocks. The author describes the first marine double-reduction-gear installation which was fitted in the S. S. *Somerset*, a steamer of 4500 s.hp. An interesting feature of this installation is that it comprises three turbines—a high-pressure and an intermediate turbine on one side of the main gear and a low-pressure turbine on the other. The subdivision of the high-pressure unit into high and intermediate is said to bring several advantages. It enables the turbines to be given higher revolutions and smaller diameter with considerable gain in efficiency and more rigid construction and increased reliability. The *Somerset*, which was built about 1918, has steamed a distance of over 200,000 miles up to the present time. Since that time over 200 British-built mercantile vessels have been fitted with double-reduction-gear turbines. For the sake of simplicity in the construction of gearing in some installations with three turbines the high-pressure and intermediate-pressure turbines have been arranged in tandem driving one primary pinion, while the low-pressure turbines drive the other.

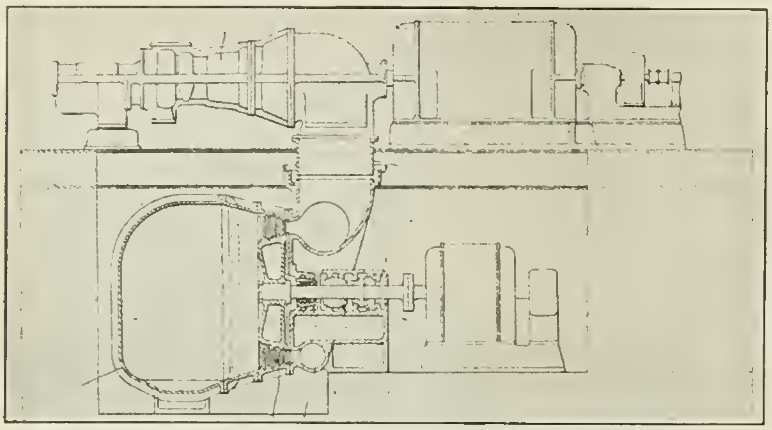

Fig. 7 Power-Plant Arrangement Involving Supplementary Turbine as Substitute for the Last Stages of Main Turbine

The author describes various ways of blade fitting and formation as well as methods of attaching the blades. A brief discussion of the relative efficiencies of the various types of blading is given.

The subject of the ability of the turbine to utilize large expansion ratios and extract the energy from the steam down to the lowest limits of pressure is discussed in some detail. The author believes that possibly the best solution of the whole exhaust-area problem in large machines is to reduce the revolutions of the last portion of the turbine in a supplementary turbine arranged in the closest possible proximity to the condenser. This enables large areas to be provided without excessive stress in the blades or in the disks which carry them. Fig. 7 shows an arrangement of this nature. (*Journal of the Royal Society of Arts*, vol. 71, no. 3696, Sept. 21, 1923, pp. 743–760, 20 figs., *hg*)

RAILROAD ENGINEERING (See also Testing and Measurements)

One-Piece Cast-Steel Freight-Car Underframe. Description of a one-piece steel underframe cast by the Commonwealth Steel Co., for the Southern Pacific, which road has recently applied underframes of this type to ten new 80,000-lb. capacity double-sheathed box cars.

The real reason why this type of frame has not been used more extensively before has lain in the difficulty of successfully casting large unit frames with thin sections. As it is, the unit cast-steel underframe, center sills, and body bolsters bring the light weight of the cars up to 46,600 lb. as compared with 46,270 lb. for similar cars with a built-up underframe. Further refinement is expected to make possible the reduction of this weight.

The original article contains drawings showing the principal dimensions and sections of the new underframe. It is cast so as to form two center sills, each of Z-section, 9 in. high, 3/4 in. thick in the web, and 7/8 in. thick through the flanges. These are approximately 30 ft. long between the inside flanges of the body bolsters.

The new development is of particular interest at a time when the railroads are being urged to adopt a standard underframe of rolled sections. (*Railway Review*, vol. 73, no. 13, Sept. 29, 1923, pp. 447–449, *d*)

Reinforced-Concrete Freight Cars

Freight Cars Made of Reinforced Concrete, Professor Kleinlogel. Experiments made about three years ago at the car shops of H. Fuchs, Heidelberg, Germany, led to the construction of a 20-ton coal car built for a portland cement works company. This car has said to have given satisfactory service for a considerable time.

About the same time (1919 or 1920) the same shops built a 15-ton freight car of the standard open type. This car was used for certain experiments. For example, it was run with speeds up to 21 km. per hr. into stop blocks placed on one rail and also into steel cars placed in its way. After each of these tests it was subjected to a careful and thorough examination. During the first experiments the car was run empty; afterward it was loaded with 17 tons of ore. The shock of collision was sometimes so tremendous that it could be heard for miles. Notwithstanding this the reinforced-concrete frame stood the tests admirably. No alteration in the condition of the fastenings and no crack in the construction could be ascertained.

The dead weight of the reinforced-concrete car is somewhat greater than that of the steel car, but the former is said to run much steadier than the latter. It is claimed that it is less subject to wear and that there is no danger of its rusting. Fig. 8 shows a sketch of the 15-ton reinforced-concrete car. (*Engineering Progress*, vol. 4, no. 8, Aug., 1923, pp. 164, 3 figs., *d*)

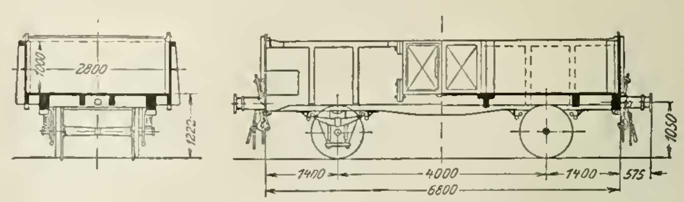

Fig. 8 Sketch of a 15-Ton Reinforced-Concrete Car

American Locomotives in France, M. Lunier.[1] In 1921 the Paris-Orleans Railway placed in service 50 Pacific-type locomotives with simple cylinders and superheaters built by the American Locomotive Company. They are essentially of American design, with some modifications, however, suggested by French practice. Thus the piston valves are of the French type and have inside admission.

In addition to the usual American equipment the locomotives were equipped with a speed indicator and recorder. In regular service these machines proved to be more efficient than the French compound locomotives and had a smaller fuel consumption. These locomotives, in which the superheating surface is 775 sq. ft. as against 684 sq. ft. for the four-cylinder compound locomotives with which they are compared, operate in general with a temperature of superheated steam at the admission to the cylinders higher than that which can be obtained with the compound.

During the comparative tests made in July and August, 1921, the average temperature of the superheated steam was 642 deg. fahr. on the simple locomotive and only 556 deg. fahr. on the compound locomotive for identical trains. This temperature was measured by means of a Fournier pyrometer of the most recent type,

[1] Parsons Marine Turbine Co., England.

[1] Inspector of Equipment, Paris-Orleans Railway.

having in place of the old cylinder reservoir with a protecting bushing, a reservoir formed of helical tube plunged directly into the current of steam. (*Railway Mechanical Engineer*, vol. 7, no. 10, Oct., 1923, pp. 679–680, 2 figs., *d*)

REFRIGERATION

Cold as a Method of Energy Accumulation, Edmund Altenkirch. The author discusses in considerable detail the use of refrigeration as a means for the accumulation of energy. The basis of his views was explained in his paper before the International Congress for Refrigeration in 1913. (Compare *The Journal of The American Society of Mechanical Engineers*, vol. 35, no. 10, Oct., 1913, p. 1574 and Mechanical Engineering, vol. 44, no. 5, May, 1922, pp. 320–321.) (*Zeitschrift für des gesamte Kälte-Industrie*, vol. 30, no. 8, Aug., 1923, pp. 89–93, 1 fig., *tm*)

SPECIAL MACHINERY

Reeling and Straightening Machines, W. H. A. Robertson. The first of a series of articles, of interest because while machines of this character have been used for a long time, there is comparatively little published information on their design. The present article describes only standard types and, in particular, the standard straightening machine and bar reeling machines, beginning with the first machine designed in 1865 by James Robertson. Bar reeling machines with chain-driven rollers and the conventional type of tube reeling machines have tubes ranging from 10 to 24 in. in diameter. (*Machinery* (Lond.), vol. 23, no. 575, Oct. 4, 1923, pp. 21–24, 8 figs., *d*)

TESTING AND MEASUREMENTS

The Relation Between the Dynamic and the Static Tensile Tests, Harold Albert Nisley. The purpose of the investigation was to determine the relation between the static test and the impact test, and among other things to compare the amounts of energy absorbed by specimens of a given material when ruptured under static and dynamic conditions. A number of attempts have been made to develop a definite percentage relationship between the results obtained by the two methods. The conclusions arrived at in the various cases have been more or less conflicting.

In this investigation a particular steel was selected and its structure made to vary over a wide range by widely differing heat treatments. In the case of the static tests, the corresponding loads, elongations, and reductions of area were recorded for each specimen through the ultimate up to the point of rupture. The total work done was then determined in each case by integrating the plotted results. Thus it was possible to make a direct comparison of the total energy required for rupture of specimens when tested statically and when tested dynamically.

The dynamic tests were carried out on a Charpy machine of 300 kg-m. capacity, while for the static tests a Riehlé machine was used. The steel selected for this investigation was a plain carbon steel containing 0.39 carbon, 0.70 manganese, 0.263 silicon, 0.34 nickel, 0.11 chromium, 0.048 phosphorus, and 0.043 sulphur. To obtain a wide range of variations of internal structure, six different heat treatments were applied. The details of these are specified in the original article.

The comparative results are presented in the form of a table. From these it would appear that there is no fixed percentage relationship between the results obtained on a particular steel by so-called static and dynamic tensile tests. This relationship is apparently a function of the structure imparted to the steel by different treatments. However, the variation of the relationship is not large and seems to be confined to a certain limited range. From the data obtainable from static tensile tests on this particular steel, the reduction of area seems to be the best criterion of the shock-resisting qualities of the material. (Paper submitted in partial fulfillment of the requirements for the degree of Master of Science in Mechanical Engineering from the Massachusetts Institute of Technology, 1923, under the direction of the Faculty Board of the Ordnance School at Watertown Arsenal. Abstracted through *Army Ordnance*, vol. 4, no. 20, September-October, 1923, pp. 88–93, 4 figs., *e*)

A Vibration Testing Machine

Determination of Mechanical Problems by Means of Vibration Tests, C. Bethel.[1] Mechanical performance under vibration cannot, as a rule, be calculated. This is because little is known about the nature of the majority of vibrations. Designs for service involving vibration are made very largely from experience, which is in some cases a long and expensive method.

More satisfactory results can be obtained if the nature of the effect of the vibration is first determined by test. In some cases this can be done by testing a piece of apparatus on the vibrating machine. Several of these have been developed during the last few years for different classes of testing. For example, a special machine to test locomotive collector rings; a hammer-type machine for low-frequency vibration tests, as tests on bearing flanges. The author describes in particular a vibrating machine of the disk type built for general vibration testing.

In this machine the part to be tested is clamped on the table which is supported by the bearings of the upper disk. The vibration is caused by flat places machined on the lower disk and may be varied in intensity by varying the contact pressure between the disks by compressed air. The floating disk and table are held against the driver disk by air pistons, and the character of the vibration may be changed by changing the air pressure on the pistons. The same is true of a change in the speed of the machine. It is very important to make vibration machines rugged, and this machine is sufficiently so to enable the operator to start it and then go about other work elsewhere, returning to it occasionally to note the condition of the test. The vibration produced is so severe that it is distinctly uncomfortable to be in the same room with the machine.

This machine successfully reproduces a large number of service conditions and gives a means of shortening development enormously. Some of the more common classes of vibrations met with are: (*a*) High-frequency vibration; (*b*) combination of high-frequency vibration with shocks or impacts, and (*c*) impacts.

Brushholder parts afford a very good example of the first class. They are subjected to a very high-frequency vibration. This vibration often results in a disastrous wear of all of the moving brushholder parts. The machine has been used to improve these parts.

Railway-motor gear cases are subjected to the second class of vibration. This is a case of the combination of practically every vibration to which the motor is subjected, from a high-frequency gear vibration to the more or less infrequent road shocks. The magnitude of these forces cannot be calculated but they can be reproduced on the vibrating machine, and the gear-case failures on the machine compare in every way with service failures.

Bearing vibration comes under the third class. It consists mostly of more or less infrequent shocks, with very little high-frequency vibration. The shocks are often of sufficient severity to cause failures of the babbitt. Vibration tests afford a quick means of determining the best babbitt and method of anchoring for a given bearing and service.

The list could be extended almost indefinitely, but the examples mentioned will convey an idea of the different kinds of vibration which are encountered every day and for which there is no known means of calculating. Most problems of this kind may be solved by reproducing them on a vibrating machine.

The results of these tests have shown the great value of reproducing service vibrations experimentally to determine the ability of a piece of apparatus to meet actual service requirements. By weeding out the weakest parts of a piece of apparatus, its useful life and range of application are greatly extended. (*The Electric Journal*, vol. 20, no. 10, Oct., 1923, pp. 371–373, 5 figs., *dp*)

A Carbon Monoxide Meter

A Carbon Monoxide Meter. Description of an apparatus for determining the carbon monoxide content of flue gases electrically. This is of interest because precise control of the percentage of CO in flue gases may be of considerable importance under certain conditions.

The operation of the meter is based on the catalytic action of heated platinum wire in producing combustion of CO with oxygen.

[1] Motor Engineering Dept., Westinghouse Elec. & Mfg. Co., East Pittsburgh, Pa.

Referring to Fig. 9, *A* and *B* are two small platinum wires, each passing through the center of cylindrical chambers in two separate metal blocks. *B* is the comparison wire and *A* is the measuring wire in the chamber through which the sample of flue gas passes slowly. The wires are heated to a temperature of about 800 deg. fahr. by an electric current. Usually enough oxygen is present in the waste gases for the combustion of the CO and hydrogen, but to make certain of this, air to the amount of 20 per cent of the gas volume is admitted through the small passage *E*, Fig. 10. The catalytic action causes the CO and H_2 to burn along the surface of the wire *A*, thereby raising its temperature and increasing the resistance in almost exact proportion to the amount of these gases present. When considerable amounts of CO are present the wire is heated to a brilliant glow. As *B* maintains instant temperature and resistance, the Wheatstone-bridge circuit, consisting of the wires *A* and *B*, and the resistances *C* and *D*, becomes unbalanced and causes an indication on the galvanometers *F* and *H*. These instruments are calibrated in percentage of CO or CO plus H_2. As the combustion heat of a given volume of H_2 is almost identical with that of CO, the CO meter may serve for a mixture containing both gases. For boiler-house practice it is not necessary to know what fraction of the sum is CO and what fraction is H_2; the important thing is the indication that these combustibles are present and to what extent combustion is incomplete. Methane or other hydrocarbons are not indicated, but they occur only in small quantities except where the CO content is extremely high.

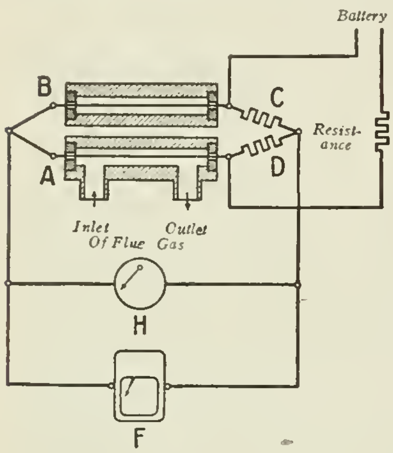

Fig. 9 Diagrammatic Sketch of CO Meter

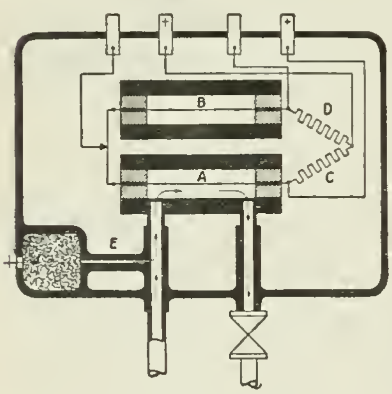

Fig. 10 Diagrammatic Sketch of CO Meter

The galvanometer *H*, Fig. 9, is a waterproof wall-type instrument suitable for mounting on the front of the boiler, and *F* is a recorder usually placed in the superintendent's office.

The CO meter requires across its terminals a voltage of 2.7 and the current passing through the Wheatstone bridge of the CO meter amounts at this voltage to 0.85 ampere. To supply this current a storage battery may be used or the CO meter may be connected to a direct-current line of 120 or 240 volts; in both cases a suitable resistance must be provided in series with the CO meter to keep the current within the given limit of 0.85 ampere.

In general, the indications of combustible gases by this instrument are accurate within a few tenths of one per cent. Greater accuracy than this cannot be expected, and in practice is not necessary. What is required is a sure indication that combustible gases are being wasted, and this the carbon monoxide meter, it is stated, cannot fail to show if properly installed. (*Fuels and Furnaces*, vol. 1, no. 6, Oct., 1923, pp. 471–474, 4 figs., *d*)

THERMODYNAMICS (See also Refrigeration)

Variation of Specific Heat of Gases with Temperature

Variation of Specific Heat of Gases with Temperature According to the Most Recent Investigations, H. Muraour. Data based on the work of Holborn and Henning and used more recently by Pier and Bjerrum at the Nernst Laboratory.

The results obtained at the Nernst Laboratory would lead one to adopt, at least for high temperatures, in particular for diatomic gases, values of specific heats materially different from those obtained by the use of the equations of Mallard and LeChatelier, as would appear from the curves of Fig. 11 and tables in the original article.

Apparently from Fig. 11 the new values of specific heats do not lend themselves to expression by a linear formula, in particular in the case of carbon dioxide and water vapor. For practical purposes, however, Kast has proposed the use of the formula usually employed for the computation of temperatures of explosion with certain variations. The ordinary formula is

$$t = \frac{-A \sqrt{A^2 + 4bQ}}{2b}$$

and Kast has proposed the following straight-line formulas for calculating, namely,

For diatomic gases........	$4.8 + 0.00045\,t$
For carbon dioxide........	$9.0 + 0.00058\,t$
For water vapor..........	$4.0 + 0.00215\,t$

By means of these formulas Kast has calculated the probable values of the mean specific molecular heats at constant volume

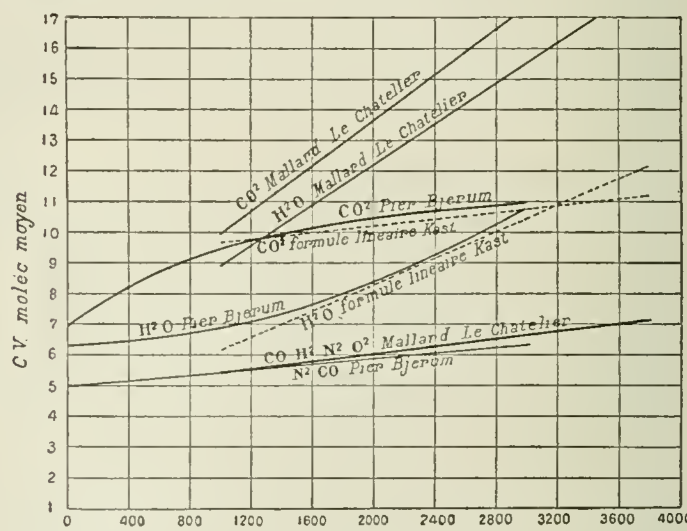

Fig. 11 Curves of Specific Heats of Various Gases at High Temperatures

(*C. V. molec moyen* = true mean molecular heat; *formule linéaire* = straight-line equation. The abscissas are in degrees centigrade.)

between 0 deg. cent. and *t* deg. cent. for the region of 3000 to 4000 deg. These are:

	Temperature, Deg. Cent.					
	3000	3200	3400	3600	3800	4000
Diatomic gases........	6.1	6.2	6.3	6.4	6.5	6.6
Carbon dioxide........	10.95	11.1	11.2	11.4	11.45	11.5
Water vapor..........	10.5	10.9	11.4	11.7	12.1	12.5

It should be noted that these values, in particular those for water vapor, have been obtained not by measurement but by extrapolation and should not be considered as fully reliable.

The specific heats of methane, ethylene, acetylene, and benzol are also discussed, likewise the industrial applications of the new values.

A bibliography of the subject comprising references dating back to 1880 is appended to the article. (*Chimie & Industrie*, vol. 10, no. 1, July, 1923, pp. 23–29, 1 fig., *t*)

CLASSIFICATION OF ARTICLES

Articles appearing in the Survey are classified as *c* comparative; *d* descriptive; *e* experimental; *g* general; *h* historical; *m* mathematical; *p* practical; *s* statistical; *t* theoretical. Articles of especial merit are rated *A* by the reviewer. Opinions expressed are those of the reviewer, not of the Society.

Second Revision of A.S.M.E. Boiler Code

PROPOSED revisions of the A.S.M.E. Boiler Code have, as a result of the recent revision work of the Boiler Code Committee, been published in the following issues of Mechanical Engineering:

July, 1922,	page 460	April, 1923,	page 263
August, 1922	page 544	May, 1923,	page 318
December, 1922,	page 850	June, 1923	page 379

The Public Hearing required in connection with the discussion of the proposed revisions was held on December 4, 1922, in connection with the Annual Meeting of the Society. As a result of the suggestions received at this Public Hearing much further careful consideration has been given to the revision schedule by the Boiler Code Committee during the current year which has resulted in the further schedule of proposed modifications of both the Power Boiler Section of the Code and the material specifications section. These modifications are here presented for the information of every one interested in the application of the A.S.M.E. Boiler Code.

It is the request of the Committee that these revisions be fully and freely discussed so that it may be possible for any one to suggest changes before the rules are brought to final form and presented to the Council for approval. Discussions should be mailed to C. W. Obert, Secretary of the Boiler Code Committee, 29 West 39th St., New York, N. Y., in order that they may be considered by the Boiler Code Committee.

The revisions here published embrace paragraphs that appeared in the 1918 Edition of the A.S.M.E. Boiler Code and all paragraphs without prefix letters refer to paragraphs of similar number in that edition. In addition, however, there are presented revisions of the material specifications that have been approved by the Boiler Code Committee to replace specifications in the present edition of the Code; all of these specifications which are designated in the paragraph numbers by the prefix letter S are here presented as modifications of the similar specifications published in the June, 1923 issue of Mechanical Engineering, pages 379 to 383.

There are also included proposed revisions of the new requirements pertaining to specifications for pipe, pipe material, and fittings used on steam boilers which new rules were originally presented in the December, 1922 issue of Mechanical Engineering, under the special paragraph number designations of the prefix letter X; of these it is proposed to incorporate paragraphs X-1 to X-6 in the Power Boiler Section of the Code, whereas the specifications for steel and wrought-iron pipe will be incorporated in the material specifications of the Code.

Boiler Code Revisions

Par. 6 Revised:

6 Steel bars or structural shapes for braces and for other boiler parts, except as otherwise specified herein, shall be of the quality designated in the Specifications for Steel Bars.

Par. 9 Revise paragraph as printed in May, 1923, issue of Mechanical Engineering to read as follows:

9 The use of bessemer steel is prohibited for the pressure parts of boilers. When the maximum allowable working pressure exceeds 160 lb. per sq. in., cross-pipes connecting the steam and water drums of water-tube boilers, headers, cross-boxes and all pressure parts of the boiler proper over 2-in. pipe size, or equivalent cross-sectional area shall be of wrought steel, or cast steel of Class B grade, as designated in the Specifications for Steel Castings. Malleable iron as designated in the Specifications for Malleable Castings may be also used when the maximum allowable working pressure does not exceed 350 lb. per sq. in., provided the form and size of the internal cross-section perpendicular to the longest dimension of the box is such that it will fall within a 7-in. by 7-in. rectangle. Seamless tubes or lap-welded pipe may be used for drums or other pressure parts of a boiler provided such tubes or pipes conform to the Specifications for Lap-Welded and Seamless Boiler Tubes, for Steel Pipe or for Wrought-Iron Pipe.

Par. 21 Revise paragraph as printed in May, 1923, issue of Mechanical Engineering to read as follows:

21 *Tubes and Nipples for Water-Tube Boilers.* The maximum allowable working pressures for steel or wrought-iron tubes or nipples used in water-tube boilers shall be for the various diameters and minimum gages measured by Birmingham wire gage, as given in Tables 2*a* or 2*b*. Open-hearth steel pipe or wrought-iron pipe not to exceed $1^1/_2$ in. standard pipe size which meets the pipe specifications may be used for water-tube boilers for a working pressure not to exceed 250 lb. per sq. in., when screwed in the sheet, provided the wall thickness is at least 50 per cent greater than the minimum wall thickness required by Table 2*a* or 2*b*. The maximum allowable working pressure for copper tubes or nipples used in water-tube boilers, shall be for the various diameters and minimum gages measured by Birmingham wire gage as given in Table $2^1/_2$, but not to be used for pressures to exceed 250 lb. Copper tubes shall not be used with superheated steam.

Par. 22 Revise paragraph as printed in April, 1923, issue of Mechanical Engineering to read as follows:

22 *Tubes for Fire-Tube Boilers.* The minimum thicknesses of tubes used in fire-tube boilers measured by Birmingham wire gage for maximum allowable working pressures not exceeding 175 lb. per sq. in., shall be as follows:

MAXIMUM ALLOWABLE WORKING PRESSURES FOR STEEL OR WROUGHT-IRON TUBES OR NIPPLES FOR FIRE-TUBE BOILERS

	Gage—B.W.G.	
	Steel or Wrought Iron	Copper
Diameters 1 in. or over, but less than $2^1/_2$ in.	13	10
Diameters $2^1/_2$ in. or over, but less than $3^1/_4$ in.	12	8
Diameters $3^1/_4$ in. or over, but less than 4 in.	11	7
Diameters 4 in. or over, but less than 5 in.	10	6
Diameter 5 in.	9	5

For each increase of one gage in thickness above that shown in the table, the maximum allowable working pressure will be increased by 200 lb. divided by the diameter of the tube in inches.

Copper boiler tubes shall not be used for pressures above 250 lb. per sq. in., or where the temperature of the water or steam in contact with tubes subjected to external pressure is in excess of 406 deg. fahr.

Table $2^1/_2$ Revise heading as printed in May, 1923, issue of Mechanical Engineering to read as follows:

TABLE $2^1/_2$ MAXIMUM ALLOWABLE WORKING PRESSURES FOR COPPER TUBES FOR WATER-TUBE BOILERS AND BOILERS WITH TUBES SUBJECTED TO EXTERNAL PRESSURE

(For use at pressures not to exceed 250 lb. per sq. in. or temperatures not to exceed 406 deg. fahr.)

Par. 28c Reword this section as follows, and renumber as Par. 3*b*

3*b* If desired, both flange and firebox steel of lower tensile strength than specified may be used for an entire boiler or part thereof, the desired tensile limits to be specified with a range of 10,000 lb. per sq. in. All such steel shall conform to the Specifications for Steel Boiler Plate, excepting that the lower limit for carbon in the case of firebox steel may be less than 0.12 per cent for steels having the lower tensile strength.

Par. 185 Revise paragraph as printed in May, 1923, issue of Mechanical Engineering to read as follows:

185 When shell plates exceed $^5/_8$ in. in thickness in horizontal-return-tubular boilers, the portion of the plates forming the laps of the circumferential joints, where exposed to the fire or products of combustion, shall be planed or milled down as shown in Fig. 8, to a thickness of not over $^9/_{16}$ in. provided the requirement in Par. 184 is complied with. The fillet at the edge of the planing may be not less than 1 in. radius.

Par. 186 Revised:

186 *Welded Joints.* The ultimate strength of a joint which has been properly welded by the forging process, shall be taken as 35,000 lb. per sq. in., with steel plates having a range in tensile strength of 45,000 to 55,000 lb. per sq. in. Autogenous welding

TABLE 2a MAXIMUM ALLOWABLE WORKING PRESSURES FOR SEAMLESS AND LAP-WELDED STEEL TUBES OR NIPPLES FOR WATER-TUBE BOILERS FOR DIFFERENT DIAMETERS AND GAGES OF TUBES

Outside diam. of tube in inches, D	Minimum Gage—B.W.G.												
	17 t = 0.058	16 t = 0.065	15 t = 0.072	14 t = 0.083	13 t = 0.095	12 t = 0.109	11 t = 0.120	10 t = 0.134	9 t = 0.148	8 t = 0.165	7 t = 0.180	6 t = 0.203	5 t = 0.220
1/2	434	686	...	...	...	...	...	...	...	...	...	...	...
3/4	206	374	542	806	...	...	...	...	...	...	...	...	...
1	...	218	344	542	758	...	...	...	...	...	...	...	...
1 1/8	...	166	278	454	646	870	...	...	...	...	...	...	...
1 1/4	...	124	225	383	557	758	...	...	...	...	...	...	...
1 1/2	...	...	146	278	422	590	722	...	...	...	...	...	...
1 3/4	...	...	...	203	326	470	583	727	871	...	...	...	...
2	...	...	...	146	254	380	479	605	731	...	...	...	...
2 1/4	...	...	...	...	198	310	398	510	622	758	...	...	...
2 1/2	...	...	...	...	153	254	333	434	535	657	765	...	...
2 3/4	...	...	...	...	117	208	280	372	464	575	673	824	...
3	...	...	...	...	...	170	236	320	404	506	596	734	836
3 1/4	...	...	...	...	...	...	199	276	354	448	531	658	752
3 1/2	...	...	...	...	...	...	167	238	310	398	475	594	681
3 3/4	...	...	...	...	...	...	139	206	273	355	427	537	619
4	...	...	...	...	...	...	...	178	240	317	385	488	565
4 1/2	...	...	...	...	...	...	...	...	186	254	314	406	474
5	...	...	...	...	...	...	...	...	142	204	258	340	402

Provided the working pressure for lap welded steel tubes does not exceed........................

$$P = \frac{(t - 0.039)}{D} 18{,}000 - 250$$

$$P = \frac{(t - 0.039)}{D} 14{,}000$$

where P = maximum allowable working pressure, lb. per sq. in.
t = thickness of tube wall, in.
D = outside diameter of tube, in.

For pressures in excess of those given in the table, formulas shall govern.

Note: Maximum allowable working pressures for superheater tubes shall be the same as for boiler tubes.

TABLE 2b MAXIMUM ALLOWABLE WORKING PRESSURES FOR LAP-WELDED WROUGHT-IRON TUBES OR NIPPLES FOR WATER-TUBE BOILERS FOR DIFFERENT DIAMETERS AND GAGES OF TUBES

Outside diam of tube in inches, D	Minimum Gage—B.W.G.												
	17 t = 0.058	16 t = 0.065	15 t = 0.072	14 t = 0.083	13 t = 0.095	12 t = 0.109	11 t = 0.120	10 t = 0.134	9 t = 0.148	8 t = 0.165	7 t = 0.180	6 t = 0.203	5 t = 0.220
1/2	402	551	700	934	...	...	...	...	...	...	...	...	...
3/4	206	367	466	622	791	...	...	...	...	...	...	...	...
1	...	218	344	466	593	742	...	...	...	...	...	...	...
1 1/8	...	166	278	415	527	660	763	...	...	...	...	...	...
1 1/4	...	124	225	373	475	593	687	805	...	...	...	...	...
1 1/2	...	...	146	278	396	494	572	670	770	...	...	...	...
1 3/4	...	...	...	203	326	424	490	575	660	763	...	...	...
2	...	...	...	146	254	371	430	502	577	668	747	...	...
2 1/4	...	...	...	...	198	310	382	447	513	594	665	773	...
2 1/2	...	...	...	...	153	254	333	401	462	535	598	696	766
2 3/4	...	...	...	...	117	208	280	366	420	485	543	633	697
3	...	...	...	...	...	170	236	320	385	445	497	580	639
3 1/4	...	...	...	...	...	...	199	276	354	411	460	535	590
3 1/2	...	...	...	...	...	...	167	238	310	382	427	496	548
3 3/4	...	...	...	...	...	...	139	206	273	355	399	464	511
4	...	...	...	...	...	...	...	178	240	317	374	435	480
4 1/2	...	...	...	...	...	...	...	...	186	254	314	387	426
5	...	...	...	...	...	...	...	...	142	204	258	340	383

Provided the working pressure does not exceed

$$P = \frac{(t - 0.039)}{D} 18{,}000 - 250$$

$$P = \frac{(t - 0.039)}{D} 10{,}600$$

where P = maximum allowable working pressure, lb. per sq. in.
t = thickness of tube wall, in.
D = outside diameter of tube, in.

For pressures in excess of those given in the table the formula shall govern.

Note: Maximum allowable working pressure for superheater tubes shall be the same as for boiler tubes.

may be used in boilers in cases where the strain is carried by other construction which conforms to the requirements of the Code and where the safety of the structure is not dependent upon the strength of the weld.

Par. 190 Cancel revision printed in May, 1923, issue of Mechanical Engineering.

Par. 199 Revise Value of C = 135 as printed in December, 1922, issue of Mechanical Engineering to read as follows:

C = 135 for stays screwed through plates and fitted with single nuts outside of plate or with inside and outside nuts omitting washers (see Par. 203).

Par. 201 Revise paragraph as printed in July, 1922, issue of Mechanical Engineering to read as follows:

201 *Structural Reinforcements.* When channel irons or other structural shapes are securely riveted to the boiler heads for attaching through stays, the transverse stress on such members shall not exceed 12,500 lb. per sq. in. In computing the stress, the section modulus of the member shall be used without addition for the strength of the plate. The spacing of the rivets over the supported surface shall be determined by the formula in Par. 199 using 135 for the value of C.

If the outstanding legs of the two members are fastened together so that they act as one member in resisting the bending action produced by the load on the rivets attaching the members to the head of the boiler, and provided that the spacing of these rivets attaching the members to the head is approximately uniform, the members may be computed as a single beam uniformly loaded and supported at the points where the through braces are attached.

Table 5 Revised:

TABLE 5 MAXIMUM ALLOWABLE STRESSES FOR STAYBOLTS AND STAYS OR BRACES

Description of staybolts and stays or braces	Stresses, lb. per sq. in.	
	For lengths between supports not exceeding 120 diameters[1]	For lengths between supports exceeding 120 diameters[1]
a Unwelded or flexible staybolts less than twenty diameters[1] long, screwed through plates with ends riveted over........................	7,500	....
b Hollow steel staybolts less than twenty diameters[1] long, screwed through plates with ends riveted over........................	8,000	....
c Unwelded stays or braces and unwelded portions of welded stays or braces............	9,500	8,500
d Steel through stays or braces exceeding 1 1/2 in. diameter[1]................................	10,400	9,000
e Welded portions of stays or braces..........	6,000	6,000

[1] Diameters taken at body of stay

Par. 245 Revised:

245 *Cast-Iron and Malleable-Iron Headers.* The pressure allowed on a water-tube boiler shall not exceed 160 lb. per sq. in. when the tubes are secured to cast-iron headers, nor 350 lb. per sq. in. when the tubes are secured to malleable-iron headers. The

form and size of the internal cross-section perpendicular to the longer axis of a cast-iron or malleable-iron header at any point shall be such that it will fall within a 7 in. by 7 in. rectangle.

Par. 246 Revised:

246*a* The cast iron used for the headers of water-tube boilers shall conform to the Specifications for Gray-Iron Castings given in Pars. ———, the header to be arbitrarily classified as a "medium casting" as to physical properties and tests, and as a "light casting" as to chemical properties. The malleable iron used for headers of water-tube boilers shall conform to the Specifications for Malleable Castings given in Pars. ————.

b A cast-iron header when tested to destruction, shall withstand a hydrostatic pressure of at least 1200 lb. per sq. in. and a malleable iron header 2250 lb. A hydrostatic test applied to all new headers or elements with tube attached shall be 500 lb. per sq. in. when cast-iron headers or elements are used and two and one-half times the working pressure when malleable iron is used, although the minimum test pressure with malleable-iron headers or elements shall be 500 lb. per sq. in.

Par. 266 Revised:

266 A vertical fire-tube boiler, except boilers of steam fire engines or boilers 24 in. or less in diameter, shall have not less than seven handholes, located as follows: Three in the shell at or about the line of the crown sheet; one in the shell at or about the water line or opposite the fusible plug when used; three in the shell at the lower part of the waterleg. A vertical fire-tube boiler, submerged-tube type, shall have two or more handholes in the shell, in line with the upper tube sheet. All boilers 24 in. or less in diameter shall have at least one opening for inspection and two openings in addition to the blow-off for washing out the boiler, these openings to be fitted with brass plugs.

Par. 269 Revise Paragraph as printed in December, 1922, and April, 1923, issues of Mechanical Engineering to read as follows:

269 *Safety Valve Requirements.* Each boiler having more than either 500 sq. ft. of water-heating surface or in which the generating capacity exceeds 2000 lb. per hour, shall have two or more safety valves. The method of computing the steam generating capacity of the boiler shall be as given in Par. 420 of the Appendix.

Par. 272 Revise Paragraph as printed in December, 1922, issue of Mechanical Engineering to read as follows:

272 All safety valves shall be so constructed that no shocks detrimental to the valve or to the boiler are produced and so that no failure of any part can obstruct the free and full discharge of steam from the valve. Safety valves may be of the direct spring-loaded pop type, with seat and bearing surface of the disk inclined at any angle between 45 deg. and 90 deg. inclusive, to the center line of the spindle. The maximum rated capacity of a safety valve shall be determined at a pressure 3 per cent in excess of that at which the valve is set to blow and with a blow down of not more than 4 per cent of the set pressure, the blow down to be in no case less than 2 lb.

Safety valves may be used which give any opening up to the full discharge capacity of the area of the opening of the inlet of the valve (see Par. 273*b*), provided the movement of the valve is such as not to induce lifting of water in the boiler.

Dead-weight or weighted-lever safety valves shall not be used.

Par. 273 Revise paragraph as printed in December, 1922, and April, 1923, issues of Mechanical Engineering to read as follows:

273 Each safety valve ½-in. size and larger shall be plainly marked by the manufacturer in such a way that the markings will not be obliterated in service. The markings may be stamped or cast on the casing, or stamped or cast on a plate or plates securely fastened to the casing, and shall contain the following:

a The name or identifying trademark of the manufacturer
b Size—The pipe size of valve inlet
(Where the valve inlet is not threaded, the initial diameter of the inlet shall be not less than the inside diameter of a standard pipe of the same nominal diameter as that of the valve)
c Pres.—The steam pressure at which it is set to blow
d B.D.—Blow down
(difference between the opening and closing pressures)
e Cap.—The weight of steam discharged in pounds per hour
(at a pressure 3 per cent higher than that for which the valve is set to blow, and with the valve adjusted for the blow down given in preceding item)
f A.S.M.E. Std.

Par. 277 Revise paragraph as printed in December, 1922, issue of Mechanical Engineering to read as follows:

277 The safety valve or valves shall be connected to the boiler independent of any other steam connection, and attached as close as possible to the boiler, without any unnecessary intervening pipe or fitting. Such intervening pipe or fitting, if used, shall not be longer than the face to face dimension (A-A) of the American Extra-Heavy Iron Flanged Tee Fitting of corresponding size shown in Table 17 and Fig. 33. Every safety valve shall be connected so as to stand in an upright position, with spindle vertical, when possible.

Par. 278 Revise paragraph as printed in April, 1923, and May, 1923, issues of Mechanical Engineering to read as follows:

278 The opening or connection between the boiler and the safety valve shall have at least the area of the valve inlet. In the case of fire-tube boilers, the openings in the boilers for safety valves shall be not less than given in Table 15 for capacities determined in accordance with Par. 274. No valve of any description shall be placed between the required safety valve or valves and the boiler, nor on the discharge pipe between the safety valve and the atmosphere. When a discharge pipe is used, the cross-sectional area shall be not less than the full area of the valve outlet or of the total of the areas of the valve outlets discharging thereinto, and shall be as short and straight as possible and so arranged as to avoid undue stresses on the valve or valves.

All safety-valve discharges shall be so located or piped as to be carried clear from running boards or platforms. Ample provision for gravity drain shall be made in the discharge pipe, at or near each safety valve, and where water of condensation may collect. Each valve shall have an open gravity drain through the casing below the level of the valve seat. For iron- and steel-bodied valves exceeding 2-in. size, the drain holes shall be tapped.

Par. 279 Revise paragraph as printed in December, 1922, issue of Mechanical Engineering to read as follows:

279 If a muffler is used on a safety valve it shall have sufficient

TABLE 15 MINIMUM SIZE OF BOILER OUTLETS FOR SAFETY VALVES FROM FIRE-TUBE BOILERS FOR VARIOUS DISCHARGE CAPACITIES

Gage pressure, lb. per sq. in.	Size of Boiler Outlet for Safety-Valve Connections														
	Nominal Pipe Size and Actual Diameters of Pipe Sizes, In.														
	½ 0.622	¾ 0.824	1 1.049	1¼ 1.380	1½ 1.610	2 2.067	2½ 2.469	3 3.068	3½ 3.548	4 4.026	4½ 4.506	5 5.047	6 6.065	7 7.023	8 7.981
	Lb. of Steam per Outlet per Hour														
15	49	74	131	163	245	391	486	782	1026	1303	1613	2052	2916	3909	5212
25	66	99	174	218	326	523	653	1046	1372	1742	2156	2744	3898	5226	6968
50	107	161	284	354	532	851	1064	1703	2235	2839	3513	4470	6352	8517	11356
75	148	198	393	492	738	1181	1475	2361	3099	3935	4870	6198	8805	11805	...
100	189	285	503	629	944	1510	1877	3019	3963	5032	6227	7926	11259	...	...
125	230	346	613	767	1149	1836	2299	3677	4826	6128	7583	9652	13711	...	...
150	272	408	723	904	1355	2158	2710	4335	5690	7226	8940	11380	...	...	...
175	313	470	835	1040	1561	2497	3121	4993	6553	8320	10298	13106	...	...	...
200	354	533	941	1178	1766	2826	3532	5651	7418	9420	11655	14836	...	...	...
225	395	593	1052	1315	1972	3154	3944	6310	8280	10514	13013	...	...	...	...
250	437	656	1161	1451	2177	3484	4355	6968	9143	11614	14366	...	...	...	...

outlet area to prevent back pressure from interfering with the proper operation and discharge capacity of the valve. The muffler plates or other devices shall be so constructed as to avoid any possibility of restriction of the steam passages due to deposit.

Par. 280 Revise paragraph as printed in December, 1922, and April, 1923, issues of Mechanical Engineering to read as follows:

280 When a boiler is fitted with two or more safety valves on one connection, this connection to the boiler shall have a cross-sectional area not less than the combined areas of inlet connections of all of the safety valves with which it connects and shall also meet the requirements of Par. 278.

Par. 281 Revise paragraph as printed in December, 1922, and April, 1923, issues of Mechanical Engineering to read as follows:

281 Safetey valves shall operate without chattering and shall be set and adjusted as follows: To close after blowing down not more than 4 per cent of the set pressure but not less than 2 lb. in any case. For safety valves operating on pressures up to and including 300 lb. the blow down shall not be less than 2 per cent of the set pressure. To insure the guaranteed capacity and satisfactory operation, the blow down as marked upon the valve (Par. 273*d*) shall not be reduced.

Par. 282 Revise paragraph as printed in December, 1922, issue of Mechanical Engineering to read as follows:

282 To insure the valve being free, each safety valve on boilers with maximum allowable working pressures up to and including 200 lb. per sq. in., shall have a substantial lifting device by which the valve disk may be positively lifted from its seat at least $^1/_{16}$ in. when there is no pressure on the boiler. For boilers with working pressures above 200 lb. per sq. in., the safety-valve lifting device need provide for lifting the valve disk $^1/_{16}$ in. only at such times as there is at least 75 per cent of the full working pressure upon the boiler. Except at times of general inspection, the valve should not be lifted, unless there is sufficient steam pressure on the boiler to blow the dirt and scale clean from the seat.

Par. 283 Revised:

283 The seats and disks of safety valves shall be of suitable material to resist corrosion. The seat of a safety valve shall be fastened to the body of the valve in such a way that there is no possibility of the seat lifting.

Par. 286 Revise paragraph as printed in December, 1922, issue of Mechanical Engineering to read as follows:

286 A safety valve over 3 in. size, used for pressures greater than 15 lb. per sq. in. gage, shall have a flanged inlet connection. The dimensions of flanges subjected to boiler pressure not exceeding 250 lb. shall conform to the American Extra-Heavy Standard given in Table 17 of the Appendix, except that the face of the safety valve flange and the nozzle to which it is attached may be flat and without the raised face.

Par. 289 Revise paragraph as printed in December, 1922, and April, 1923, issues of Mechanical Engineering to read as follows:

289 Every safety valve used on a superheater, discharging superheated steam, shall have a casing, including the base, body, bonnet and spindle, of steel, steel alloy, or equivalent heat-resisting material (see Par. 12). The valve shall have a flanged inlet connection, and shall have the seat and disk of nickel composition or equivalent material, and the spring fully exposed outside of the valve casing so that it shall be protected from contact with the escaping steam.

Par. 290 Revise paragraph as printed in December, 1922, issue of Mechanical Engineering to read as follows:

290 Every boiler shall have proper outlet connections for the required safety valve or valves independent of any other outside steam connection, the area of opening to be at least equal to the aggregate areas of inlet connections of all of the safety valves to be attached thereto. An internal collecting pipe, splash plate, or pan may be used, provided the total area for inlet of steam thereto is not less than twice the aggregate area of the inlet connections of the attached safety valves. The holes in such collecting pipes shall be at least $^1/_4$ in. in diameter and the least dimension in any other form of opening for inlet of steam shall be $^1/_4$ in.

Par. 291 Revised:

291 *Water Glasses and Gage Cocks.* Each boiler shall have at least one watergage glass, the lowest visible part of which shall be not less than 2 in. above the lowest permissible water level. The lowest permissible water level shall be that at which there will be no danger of overheating any part of the boiler when it is operated with the water not lower than that level.

Par. 308 Revise paragraph as printed in July, 1922, and June, 1923, issues of Mechanical Engineering to read as follows:

308 Each boiler shall have a bottom blow-off pipe, fitted with a valve or cock, in direct connection with the lowest water space practicable; the minimum size of pipe and fittings shall be 1 in. and the maximum size shall be $2^1/_2$ in. Straightway globe valves of the ordinary type as shown in Fig. $22^1/_2$, or valves of such type that dams or pockets can exist for the collection of sediment, shall not be used on such connections. Return connections of the same size or larger than the size herein specified may be used, and to which the blow-off may be connected. In such case, the blow-off must be so located that the connection may be completely drained.

Par. 311*a* Revise paragraph as printed in December, 1922, issue of Mechanical Engineering to read as follows:

311*a* On all boilers except those used for traction and portable purposes, when the maximum allowable working pressure exceeds 125 lb. per sq. in., each bottom blow-off pipe shall have two slow-opening valves, or one slow-opening valve and a cock, and such valves, or valve and cock, shall be of extra heavy construction. On a boiler having multiple blow-off pipes, a single master valve may be placed on the common blow-off pipe from the boiler, in which case only one valve on each individual blow-off is required. Two independent valves or a valve and a cock may be combined in one body provided the combined fitting is the equivalent of two independent valves or a valve and a cock so that the failure of one to operate could not affect the operation of the other.

Par. 430 Revised:

430 Each boiler may have one or more fusible plugs, located at the lowest permissible water level as follows:

a In Horizontal-Return-Tubular Boilers in the rear head, not less than 2 in. above the upper row of tubes, the measurement to be taken from the line of upper surface of tubes to the center of the plug, and projecting through the sheet not less than 1 in. When the distance between the uppermost line of tubes and the top of the steam space is 13 in. or less, the bottom of the fusible plug may come at a lesser distance than 2 in. above the upper row of tubes, but in no case shall the plug be located below the level of the top of the uppermost row of tubes.

r In Economic-Type Boilers— in the rear head not less than 2 in. above the upper row of tubes. When the distance between the uppermost line of tubes and the top of the steam space is 13 in. or less, the bottom of the fusible plug may come at a lesser distance than 2 in. above the upper row of tubes, but in no case shall the plug be located below the level of the top of the uppermost row of tubes.

s This section is to be omitted.

v For other types and new designs, fusible plugs shall be placed at the lowest permissible water level, subject to the direct radiant heat of the fire or in the direct path of the products of combustion, as near the primary combustion chamber as possible.

Manufacturers' Data Report Revise items 5 and 6 as follows:

5.	Heating Surface........sq. ft.	Built for maximum allowable work. pressure.................. (Use S.F. of 5)..........lb.
	Hydrostatic test applied?......lb.	Has material been checked with mill test reports?..........

6. Material for Shell, Straps, Heads and Furnace Sheets..........
(List all plates in this order below)

Plates for Shell, Head, etc.	Stamped Class (Firebox or Flange)	Manufactured by	Thickness In.	Stamped T.S. lb. per sq. in.	Mfrs. Test Identification No.

Yield Point lb. per sq. in.	Actual T.S. lb. per sq. in.	Elongation per cent. in 8 in.	C	Mn	P	S

Following new item to be inserted:

Diagonal and Gusset Stays.......................................
Length of Diagonal Stay (See Fig. 17) Length of line drawn at right angles to boiler head (See Fig. 17).

RULES FOR PIPE, PIPE MATERIAL AND FITTINGS USED ON STEAM BOILERS

(Published in October, 1922, issue of Mechanical Engineering)

X-2 Revised:

X-2 Steam Pipe. Pipes carrying saturated or superheated steam may be of welded or seamless pipe made of wrought iron or steel. For sizes above 3 in. in diameter the steel pipe shall be of open-hearth steel. All pipes shall be straight and free from blisters, cracks, laminations and other injurious defects. Liquor marks and lap-seam lines incidental to the manufacture of pipe will not be considered defects. Each length of pipe is to be inspected separately for defects on the inside and outside, noting particularly the character of the cross-section when cutting off crop ends. Pipe up to 3 in. in diameter may be butt-welded or lap-welded while that above 3 in. in diameter shall be lap-welded. Pipe material shall correspond with that required by the specifications of wrought-iron and steel pipe included in Par. *X-9*, et seq.

X-3 Revised:

X-3 Thickness of Steam Pipe. In determining the thickness to be used for pipes at different pressures and for temperatures not exceeding 700 deg. fahr., the following formulas are to be used:

For pipes having nominal diameters of from 1/4 in. to 5 in.,

$$P = \frac{2S}{D}(t - 0.065) - 125$$

For pipes of nominal diameter over 5 in.,

$$P = \frac{2S}{D}(t - 0.1)$$

where

P = working pressure in lb. per sq. in. above atmosphere
t = thickness of wall of pipe in inches
D = outside diameter of pipe in inches
S = 9000 lb. per sq. in. for seamless steel pipe
= 7000 lb. per sq. in. for lap-welded steel pipe
= 5000 lb. per sq. in. for butt-welded steel pipe
= 5300 lb. per sq. in. for lap-welded wrought iron
= 4500 lb. per sq. in. for butt-welded wrought iron
= 4500 lb. per sq. in. for brass pipe
= 4000 lb. per sq. in. for copper pipe.

When the temperature of the steam exceeds 700 deg. fahr., the allowable stress should be reduced.

X-4 Revised:

X-4 Feed Lines. High-pressure hot-water and cold-water lines may be made of welded or seamless pipe of wrought iron or steel as called for under Par. *X-2*. Where the water contains corrosive material or air, brass or copper tubing may be used. The allowable pressure for feed and water pipes shall be taken as 80 per cent of that for steam pipes of the corresponding sizes.

Where brass pipe is desired for finish or for any other reason it may be used. The brass and copper pipes used shall correspond to the specifications given under Pars. —— and the brass pipe shall be half-annealed in order to leave it in proper condition for use in feedwater piping.

X-5 Revised:

X-5 Blow-off Piping. Blow-off pipe is to be as heavy as required for the feed pipe, and in any case at least as heavy as extra strong size. It shall be either wrought iron or steel. Where it is desirable for reasons of corrosion, brass or copper tubing may be used.

X-6 Revised:

X-6 Pipe Bends. Pipes when bent may be made of steel or wrought iron and after bending are to be free from buckles and blisters and practically circular in cross-section. They are to be bent before being threaded or flanged, and where flanged they are to be refaced to dimensions so that they may be bolted or faced without forcing. Where the tangent length or the method of manufacture is such that the bend can be made without injury or distortion of the threaded ends of pipes or flanges, these may be bent after threading or flanging. Where possible, the tangent length of pipe at the end of each bend should be of a length equal to at least twice the nominal diameter of the pipe, although tangents may be used with lengths which are equal to the nominal diameter of the pipe. The advisable radius measured on the center line of the pipe, to which pipe should be bent, should be five or six times the nominal diameter of the pipe, although pipe may be bent to a radius equal to four times the diameter of standard pipe and three and one half times the diameter for extra strong pipe up to 12 in. Where special devices are used for bending pipes into coils, smaller radii than those recommended above may be used. The thickness of the pipe is to be determined by the formula given in Par. *X-3*. The boiler-feed-line bends are to conform with the above, while for blow-off lines the rules are to be applied to extra strong pipe.

X-7 to *X-20* Change title of specification to read as follows:
Specifications for Steel Pipe

X-21 to *X-36* Change title of specification to read as follows:
Specifications for Wrought-Iron Pipe

X-9 Revised:

X-9 Open-hearth steel shall conform to the following requirements as to chemical composition

	Lap-Welded	Seamless
Phosphorus....	not over 0.06 per cent	not over 0.005 per cent

X-11 Revised:

a Pipe shall be tested at the mill to the hydrostatic pressures specified in Table 1.

Change title of table 1 to read:

Table 1 hydrostatic pressures for welded and seamless steel pipe

Change Headings of the Fourth and Seventh Columns of the Table to read:

Lap Welded and Seamless

Delete Words "black and galvanized" in parenthesis under table 1.

Change footnote of table 1 to read:

For pipes over 12 in. in inside diameter the test pressures should be calculated by the formula; $P = 2St/D$, in which P = pressure in pounds per square inch; S = fiber stress, 12,000 lb. per sq. in. for lap-welded pipe and 16,000 lb. per sq. in. for seamless pipe; t = thickness of wall in inches; D = inside diameter in inches.

MATERIAL SPECIFICATIONS

(Published in June, 1923, issue of Mechanical Engineering)

S-8 Revised:

S-8 Check Analyses. As a substitute for check analyses in the general rules, the purchaser may make an analysis from a

broken tension-test specimen representing each plate as rolled. The chemical composition thus determined shall conform to the requirements.

S-29 Revised:

S-29 Permissible Tolerances. The diameter of the finished rivets measured cold shall not vary from that specified more than the amounts given in the following table:

	Variations in Diameter	
Diameters in Inches	Snap Gage Measurement	Ring Gage Measurement
Up to 1/2, inclusive	Under 0.022	Over 0.020
Over 1/2 to 1, inclusive	Under 0.025	Over 0.030
Over 1 to 1 1/4, inclusive	Under 0.027	Over 0.035
Over 1 1/4 to 1 1/2, inclusive	Under 0.030	Over 0.040
Over 1 1/2 to 2, inclusive	Under 0.037	Over 0.040

Snap-gage measurement shall be made at point of minimum diameter but it is not required that the rivet shall turn completely in the gage. Measurement of the maximum tolerance shall be made with a ring gage, all rivets to slip full to the head in the gage of the required size for the various diameters.

The dimensions of the rivet head shall not vary from that specified more than the amounts given in the following table:

Diameter of Rivet	Head Tolerance	
	Width	Height
1/2	+ 1/16 − 1/32	+ 1/32
9/16	+ 1/16 − 1/32	+ 1/32
5/8	+ 1/16 − 1/32	+ 1/32
11/16	+ 1/16 − 1/32	+ 1/32
3/4	+ 5/64 − 1/32	+ 1/32
7/8	+ 5/64 − 1/32	+ 1/32
1	+ 5/64 − 1/32	+ 1/32

Revise Specifications for Steel Staybolts as follows:

S-30 Solid or Hollow Staybolts. a Steel for solid or hollow bars for staybolts shall conform to the requirements for boiler rivet steel, except as follows:

b Tension Tests. The bars shall conform to the following requirements as to tensile properties:

Tensile strength lb. per sq. in., maximum	60,000
Yield point min., lb. per sq. in.	26,000
Elongation in 8 in., min., per cent	1,500,000 / Tens. Str.

c Permissible Variation in Gage. Solid or hollow bars for staybolts, not exceeding 1 1/4 in. diameter which are to be threaded as rolled, shall be truly round within 0.01 in. and shall not vary more than 0.005 in. under or more than 0.01 in. over. All other bars for staybolts shall conform to the specified tolerances for steel bars.

S-31 Seamless Tubing for Staybolts. Seamless steel tubing for threaded steel staybolts shall conform to the following requirements. This specification will not apply to stay tubes for locomotive boilers.

S-32 Chemical Composition. The steel shall conform to the following requirements as to chemical composition:

Manganese	0.30 to 0.60
Phosphorus	not over 0.04
Sulphur	not over 0.045

S-33 Check Analysis a. Analysis of two tubes in each lot of 250 tubes or less, may be made by the purchaser. The chemical compositions thus determined shall conform to the requirements specified. Drilling for analysis shall be taken from general points around each tube.

b If the analysis of one tube does not conform to the requirements specified, analysis of two additional tubes from the same lot shall be made, each of which shall conform to the requirements specified.

S-34 Tension Tests. The tubes shall conform to the following requirements as to tensile properties:

Tensile strength lb. per sq. in., maximum	60,000
Yield point, min., lb. per sq. in.	25,000
Elongation in 8 in., min., per cent	1,500,000 / Tens. Str.

S-35 Test Specimens. Test specimens shall consist of either full-section specimens or of sections cut longitudinally from a tube.

S-36 Number of Tests. a Two tension tests from each 2500 ft. of tubing shall be made, or in case the tubing from separate melts can be identified two tension tests shall be made from each melt.

b If the results of the physical tests of one specimen from any lot do not conform to the requirements specified, two additional specimens from the same lot may be tested each of which shall conform to the requirements specified.

c If any test specimen develops flaws, it may be discarded and another specimen substituted.

d If the percentage of elongation of any tension-test specimen is less than that specified, and any part of the fracture is outside the middle third of the gage length, as indicated by scribe scratches marked on the specimen before testing a retest shall be allowed.

S-37 Fracture Test. A special fracture test shall be made from each 2500 ft. of tubing by cutting partly through the wall of the tube and breaking it off when removing the crop end. The fracture thus produced shall be fine-grained.

S-38 Permissible Variation in Gage. The finished tubing shall be circular within 0.015 in., and the outside diameter shall not vary more than 0.01 in. over or under the size specified.

S-54 to *S-65* Change title of specification to read as follows:

Specifications for Boiler Rivet, Staybolt, and Extra-Refined Bar Iron

Revise specification to read as follows:

S-54 Process. Rivet and staybolt iron shall be rolled from a bloom, slab pile, or box pile made wholly from reworked all-pig puddled iron or reworked knobbled charcoal iron. The puddle mixture and the component parts of the bloom, slab pile, or box pile shall be free from any admixture of iron scrap or steel. Staybolt iron shall be double-worked; that is, twice piled.

Extra refined bar iron shall be made wholly from all-pig puddled iron and shall be free from any admixture of iron scrap or steel.

S-55 Physical Properties and Tests. The iron shall conform to the following requirements as to tensile properties:

	Rivet Iron	Staybolt Iron	Extra Refined Bar Iron
Tensile strength, lb. per sq. in.	48000–52000	48000–52000	48000–54000
Yield point, min., lb. per sq. in.:			
1 1/4 sq. in. and under in sectional area	0.6 ten. str.	0.6 ten. str.	0.6 ten. str.
Over 1 1/4 sq. in. to 4 sq. in., incl., in sectional area	0.55 ten. str.	0.55 ten. str.	0.55 ten. str.
Elongation in 8 in., min., per cent	28	30	25
Reduction of area, min., per cent	45	48	37

S-56 Cold-Bend Tests. Rivet Iron. a The test specimen shall withstand being bent cold through 180 deg. flat on itself, without fracture on the outside of the bent portion.

Staybolt Iron. b The test specimen shall withstand being bent cold through 180 deg. flat on itself in both directions, without fracture on the outside of the bent portions.

Extra Refined Bar Iron. c The bend test specimen shall withstand being bent cold through 180 deg. without fracture on the outside of the bent portion, around a pin the diameter of which is equal to the diameter or thickness of the specimen.

S-57 Hot-Bend Test. Extra Refined Bar Iron. The test specimen when heated to a temperature between 1700 and 1800 deg. fahr. shall withstand being bent through 180 deg. flat on itself without fracture on the outside of the bent portion.

S-58 Nick-Bend Tests. The test specimen when nicked 25 per cent around for round bars, and along one side for flat bars, with a tool having a 60 deg. cutting edge, to a depth of not less than 8 per cent or more than 16 per cent of the diameter or thickness of the specimen, and broken, shall show a wholly fibrous fracture.

S-59. Bend tests may be made by pressure or by blows.

S-60 Etch Tests. The cross-section of the test specimen shall be ground or polished, and etched for a sufficient period to develop the structure. For rivet and staybolt iron this test shall show the material to have been rolled from a bloom, slab pile, or box pile and to be uniform and free from steel. For extra refined bar iron the structure shall be uniform and free from steel.

S-61 Test Specimens. Test specimens shall be of the full section of material as rolled.

S-62 Number of Tests. a All bars of a given grade and size shall be piled separately, sorted in lots of 100 each. Two bars shall be selected at random from each lot or fraction thereof and tested as specified; but only one of these bars shall be etch-tested.

b If any test specimen from bars originally selected to represent

a lot of material contains surface defects not visible before testing but visible after testing, or if a tension-test specimen breaks outside the middle third of the gage length, the individual bar shall be rejected and one re-test from a different bar will be allowed.

S-63 Permissible Variations in Gage. *a* Iron bars for staybolts, not exceeding $1^1/_4$ in. diameter, which are to be threaded as rolled, shall be truly round within 0.01 in. and shall not vary more than 0.01 in. above nor more than 0.005 in. below the specified size. All other iron bars for staybolts shall conform to the specified tolerances for extra refined bar iron and rivet iron.

b For rivet iron and extra refined bar iron the bars shall conform to the standard limit gages as given in Table 1.

TABLE 1 TOLERANCES FOR RIVET IRON AND EXTRA REFINED BAR IRON

Nominal Diameter of Bars, in.	Large Size, + End, in.	Small Size — End, in.	Total Variation, in.
$^1/_4$	0.2550	0 2450	0 010
$^5/_{16}$	0.3180	0.3070	0.011
$^3/_8$	0.3810	0.3690	0 012
$^7/_{16}$	0.4440	0.4310	0 013
$^1/_2$	0.5070	0.4930	0 014
$^9/_{16}$	0.5700	0.5550	0.015
$^5/_8$	0.6330	0.6170	0.016
$^3/_4$	0.7585	0.7415	0.017
$^7/_8$	0.8840	0.8660	0.018
1	1 0095	0.9905	0.019
$1^1/_8$	1.1350	1.1150	0.020
$1^1/_4$	1.2605	1.2395	0.021
$1^3/_8$	1.3860	1.3640	0.022
$1^1/_2$	1.5115	1.4885	0.023
$1^5/_8$	1.6370	1.6130	0.024
$1^3/_4$	1.7625	1.7375	0.025
$1^7/_8$	1.8880	1.8620	0 026

Round bars 2 in. in diameter and over shall be rolled to nominal diameter.

c The widths or thicknesses of flat bars shall not vary more than two per cent from that specified.

S-64 Finish. The bars shall be smoothly rolled and free from slivers, depressions, crop ends, seams and evidences of being burnt.

S-65 Marking. The bars shall be stamped or otherwise marked as designated by the purchaser.

SPECIFICATIONS FOR COPPER BARS FOR STAYBOLTS

Revise percentage of elongation required for arsenical copper from 35 to 40.

SPECIFICATIONS FOR COPPER PIPE

New specification to be added based upon A.S.T.M. Specifications B42–23.

SPECIFICATIONS FOR BRASS PIPE

New specification to be added based upon A.S.T.M. Specifications B43–23.

A.S.M.E. Boiler Code Committee Work

THE Boiler Code Committee meets monthly for the purpose of considering communications relative to the Boiler Code. Any one desiring information as to the application of the Code is requested to communicate with the Secretary of the Committee, Mr. C. W. Obert, 29 West 39th St., New York, N. Y.

The procedure of the Committee in handling the cases is as follows: All inquiries must be in written form before they are accepted for consideration. Copies are sent by the Secretary of the Committee to all of the members of the Committee. The interpretation, in the form of a reply, is then prepared by the Committee and passed upon at a regular meeting of the Committee. This interpretation is later submitted to the Council of the Society for approval, after which it is issued to the inquirer and simultaneously published in Mechanical Engineering.

Below are given the interpretations of the Committee in Cases Nos. 419, 423 to 430 inclusive, as formulated at the meeting of September 27, 1923, and approved by the Council.

In accordance with the Committee's practice, the names of inquirers have been omitted.

Case No. 419

Inquiry: Is it permissible, under the requirements of the Code, to electrically weld the calking edges of plates instead of the usual method of mechanical calking?

Reply: In the opinion of the Boiler Code Committee, Par. 257 of the Code is mandatory in its requirement for mechanical calking. The use of electrical welding as a substitute for the usual method of mechanical calking is therefore not permissible.

Case No. 423

(In the hands of the Committee)

Case No. 424

Inquiry: Is it permissible, under Par. L-5 of the Code for Boilers of Locomotives to use dome caps of cast iron providing the cap is of sufficient thickness to safely withstand the required pressure calculated according to recognized formulas for such construction?

Reply: There is no provision in the Rules for Boilers of Locomotives for the use of cast iron other than is specified in Par. L-9 and it is the opinion of the Committee that this material is not suitable for the construction of dome caps.

Case No. 425

Inquiry: Is it permissible, under the requirements of the Boiler Code for circular furnaces, to use instead of the Adamson ring a grooved ring formed from steel plate, of thickness not less than the thickness of the furnace sheet and the U-shaped groove formed not less than 4 in. high outside and 3 in. wide inside, so as to better provide for expansion and contraction, and if so how shall it be calculated?

Reply: It is the opinion of the Committee that there is nothing in the Rules of the Boiler Code to prevent the use of the form of reinforcing ring described, but in such case the maximum allowable working pressure shall be calculated from the formula in Par. 242 for the Adamson type of furnace.

Case No. 426

(In the hands of the Committee)

Case No. 427

Inquiry: If rivet holes are drilled in an incorrect position in the shell of a boiler for a brace or for a supporting lug, and the mistaken holes are at least 6 in. from the nearest hole where the brace or lug should be applied, is it permissible to plug the incorrect holes with rivets?

Reply: There is no rule in the Code to cover the case referred to, but it is this opinion of the Committee that if the location of the mistaken holes is not such as to lower the required factor of safety for the boiler shell, there will be no objection to plugging them by rivets, provided they conform to the requirement of Par. 255 of the Boiler Code.

Case No. 428

(In the hands of the Committee)

Case No. 429

(In the hands of the Committee)

Case No. 430

Inquiry: Is it permissible, under the rules in the boiler code to insert in the blow-off pipe from a boiler, two "quarter-turn valves," each of a type formed with a taper plug operated through a cam mechanism that holds the plug firmly in its seat, yet allows it to turn freely, whereas Par. 311*a* of the Code requires two valves or a valve and a cock in such blow-off pipe?

Reply: It is the opinion of the Committee that a valve of the construction referred to employing a plug which can open the passage through the body from closed position to full open position by one-quarter turn of the plug on its axis, will come within the classification of a "cock" specified in Par. 309, and that it was the intent in Par. 311*a* that a slow-opening blow-off valve be used in connection with such a cock.

MECHANICAL ENGINEERING

A Monthly Journal Containing a Review of Progress and attainments in Mechanical Engineering and Related Fields, The Engineering Index (of current engineering literature), together with a Summary of the Activities, Papers and Proceedings of

The American Society of Mechanical Engineers

29 West 39th Street, New York

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Measurements in Ordnance Work

COLONEL Tschappet's paper, the leading article of this issue of Mechanical Engineering, deals with devices for measuring pressures and velocities of an extremely high order. Such instruments are essential if the performance of a gun is to be taken from the realm of conjecture and transferred to a more certain base of knowledge, and it is to be noted that the increased power and range of modern ordnance render the measuring problem doubly difficult. The pressures and velocities encountered in ordnance work may be employed in the future in industrial work. The Claude ammonia process, for example, operates under 1000 atmospheres pressure and a temperature of 650 deg. cent., so the day may not be far off when ordnance measuring devices may be borrowed, in principle at least, by the engineer in industry.

Engineering Education

TWO recent announcements relating to engineering education indicate that advances in that field are likely in the near future. The first is the appropriation by the Carnegie Corporation of one hundred and eight thousand dollars for research in engineering education, to be expended under the guidance of the Society for the Promotion of Engineering Education. The second is the issuance of the report of the National Industrial Conference Board on engineering education and American industry. This report points out that the increase in the use of machinery, power, and labor-saving devices, and in the elaboration of methods of control in production and distribution, increases the demand for experts and leaders with engineering and administrative training. To provide these men, the report calls for adequate training in and knowledge of fundamentals, and what is more important, a training in the power to use this knowledge in effective thought and action. The fundamentals of engineering training are stated as mathematics, the important principles of physics, chemistry, etc., principles of economics, principles that govern relations between people, history of nations, and the art of clear and correct expression in speaking, writing, and drawing.

In recent years engineering educators have often been urged to train specialists for the various industries. The findings of this report, sponsored by an industrial group, calling for men trained in fundamentals should offset the requests for specialists. The education of engineers in the fundamentals should make for a broader profession.

The problem of engineering education, however, is not so much to discover what to teach, but to maintain the high-grade teaching staffs that such education demands.

A.S.M.E. Annual Meeting and Power Exposition

THE leading places on the program for the A.S.M.E. Annual Meeting will be assigned to the topics of Reforestation and Timber Conservation, and The Fundamentals of Hydroelectric Power Development. The dates for the meeting are December 3 through 6. The two leading sessions will be held on Wednesday, December 5. In the afternoon of that day John W. Blodgett, President of the National Lumber Manufacturers' Association, will emphasize the importance of a national policy for reforestation. He will also point out the economies in lumber utilization that may be realized by a standardization program. On Wednesday evening, John R. Freeman, Past-President of The American Society of Civil Engineers and The American Society of Mechanical Engineers, will outline the fundamentals that prevail in the successful development of hydroelectric power.

The Professional Divisions are coöperating in the preparation of the program which comprises seventeen technical sessions. The list of the events for the meeting is as follows:

December 3 (Monday), Morning and Afternoon: Council Meeting and Local Sections Conference.
Evening: Presidential Address, Award of Medals and Reception.

December 4 (Tuesday), Morning: Joint Session with A.S.R.E., Textile Session, General Session and Open Discussion of Fluid Meter Report.
Afternoon: Business Meeting and Public Hearing on Power Test Codes.
Evening: Smoker and Ladies' Bridge.

December 5 (Wednesday), Morning: Fuels Session, Railroad Session, Ordnance Session.
Afternoon: Reforestation Session, Steam Research Session and Ladies' Tea.
Evening: Session on Hydroelectric Development.

December 6 (Thursday), Morning: Power Session, Machine Shop Session and Aeronautic Session.
Afternoon: Management Session, Gas Power and Water Measurement Session.
Evening: Dinner Dance.

Visits to places of industrial and engineering interest will be scheduled during the meeting.

The National Exposition of Power and Mechanical Engineering will be held in Grand Central Palace from December 3 through 8, opening daily at noon. Over 250 exhibits of power-plant apparatus, materials-handling equipment and power-transmission devices will be displayed. There will also be a series of historical exhibits and a continuous program of motion pictures.

Last year was the first year of the Power Exposition and over 47,000 engineers, operating men, and laymen viewed the exhibits. This year the space occupied is much larger and the exhibits are more diversified.

World Power Conference, London June 30-July 12, 1924

SIXTEEN countries are to participate in the first World Power Conference, to be held at the British Empire Exhibition, Wembley, London, June 30 to July 12, 1924. The British National Committee has made the first announcement of the papers that will be presented under its auspices. Among the titles and authors are: Steam Generation, by Sir James Kemnal; Steam Turbines, by the Hon. Sir Charles Parsons; Mechanical and Hydraulic Variable Transmission of Power, by Dr. H. S. Hele-Shaw; Application of Power to Rail Transport, by Roger T. Smith and C. B. Collett; Application of Power to Road Transport, by Col. R. E. Crompton; International Standardization, by C. LeMaistre; The Education and Training of the Engineer of the Future, by A. P. M. Fleming; The Importance of Greater Public Interest in Mechanical Progress, by T. C. Elder; and The Study of the Human Element in Production, by D. R. Wilson. The American Committee contemplates presenting about thirty papers at the Conference.

A Transportation Committee has been appointed to make reservations and arrangements so that those attending the Conference may travel in a body. It is expected that the American party will aggregate some two or three hundred, participation not being confined to formally appointed delegates.

Any further information regarding the American Committee's plans may be obtained by addressing O. C. Merrill, General Chairman, at the Federal Power Commission, Washington, D. C.

$108,000 for Research in Engineering Education

THE Carnegie Corporation of New York has voted the sum of $108,000 for a study of engineering education under the direction of the Society for the Promotion of Engineering Education. Of this sum $24,000 is available during the present fiscal year.

This action of the Carnegie Corporation is a direct result of the work of the Board of Investigation and Coördination appointed by the Society for the Promotion of Engineering Education to conduct an active campaign for the promotion of engineering education in the light of future needs as they may be developed, to coördinate the engineering educational activities of the various agencies interested, and to conduct research into engineering education. This Board of Investigation and Coördination laid out the following plan to which the appropriation of the Carnegie Corporation is to be devoted:

The Society for the Promotion of Engineering Education purposes during the next three years to make a discriminating study of the present state of engineering education. It is proposed that the investigations be directed to a study of the objects of engineering education and the fitness of the present-day curriculum for preparing the student for his profession. It will study the process by which the curriculum of fifty years ago has come to its present form; it will seek to set forth the nature and the weakness of the curriculum as at present administered; and it will indicate such modifications or developments as would seem to make for a sound, well-balanced, and fruitful course of study for engineering students.

The following organization and program have been adopted for this investigation:

1 The inquiry shall be carried on under the general direction of a committee appointed by the society for the Promotion of Engineering Education, with the understanding that this committee shall include at least two men chosen from outside the society and the engineering profession, whose point of view will be primarily that of the trained teacher.

2 The active conduct of the study will be under the supervision of a Director appointed by the committee, whose office shall be in New York, and if possible, in the Engineering Building. The publication of the results of the study will be also in the hands of the Director.

3 The Director shall organize committees in the faculties of as large a number of engineering schools as may be practicable, who shall coöperate with the committee in the prosecution of this study.

4 Inasmuch as a study of the engineering curriculum of American schools should include a knowledge of, and comparison with, the best schools in Europe, it is considered necessary that the Director of the Committee shall, as soon as his work is organized, visit such engineering schools of European countries as may throw light upon the best methods in engineering education.

5 It is believed that the cost of this inquiry will amount to $24,000 the first year; $36,000 the second year; and $48,000 the third year, including the cost of publication.

The investigation is in the hands of the Board of Investigation and Coördination which is made up of Charles F. Scott, Chairman, Mortimer E. Cooley, J. H. Dunlap, D. C. Jackson, F. W. McNair, P. F. Walker, and F. L. Bishop, Secretary.

Secretary Hoover Favors Sectional Control of Interstate Power

AT THE CONFERENCE of representatives of the Public Service Commissions of ten northeastern states, held in New York, October 13, 1923, Secretary Hoover emphasized the importance of coördination between public authorities and industry to further the development of the superpower system in the northeast. Mr. Hoover repeated the findings of the Superpower Report which pointed out the conservation of fifty million tons of coal per annum and a saving of five hundred million dollars per annum to be obtained by coördinated electrical power systems. He pointed out that the project had advanced to the stage where methods of regulation could be taken up, and in discussing this, spoke in part as follows:

In the matter of public relations to power development and distribution it appears to me that one of the first principles we must realize is that the whole of this development implies the free flow of power. We have thus at once created at least a physical and economic interstate question. This great development of so much public interest cannot come about unless there is a complete liquidity in movement of power back and forth across the boundaries throughout the whole of the United States. We cannot secure centralized generation, great water-power development, or interconnection of load unless there is this free flow. Without this we shall have permanently a larger cost of power and less expansion in its service. There are time-honored disputes over states rights with regard to water, and somewhat similar questions are being raised as to power. Subject always to the sovereignty of states in taxation, etc., unless all citizens irrespective of state may have the same rights as to use of power, we will destroy the hopes of a very great economic development.

I am advised that it is probably true that no embargo could be constitutionally placed upon power flow across state frontiers, but uncoördinated legislative and regulative actions by the states and the National Government might amount to economic embargoes and discrimination and thus stifle development.

Again, my argument that we must have free interstate flow of power implies free flow within the states, and applies with the same strength to the complete necessity of statewide regulation uninterfered with by municipal obstruction.

The regulation of power distribution, profits, or rates is a concept fully fixed into our governmental system.

The economical distribution of power rests, to a large degree, upon local territorial monopoly. Competitive overlap of power distribution systems would represent tremendous capital and distribution waste. When we accept the principle of monopoly we at once must accept the principle of public regulation. This is a fundamental conception upon which there is no need for dispute or argument. It is amply accepted by universal state legislation. Our states have wisely created public-service commissions with state-wide regulatory power in order that rates, profits, and distribution might be controlled.

I am not here to advocate Federal superregulation of interstate movement of power. I believe that power development and distribution would find its greatest solution in coördinated state regulation, perhaps with assistance and coöperation of the Federal Government, rather than in any superstructure of authority such as has been found necessary in transportation, unless of course necessities of the case cannot be attained otherwise.

One phase of public relationship is involved in the great water-power development of the St. Lawrence. It is of vital importance as an enormous contribution to the whole northeastern states. The American share would amount to 1,200,000 horsepower producible at a cost far lower than any form of fuel generation. It is a pitiable waste today and can only be mobilized by coöperation of the Federal Government.

In any event, the problems we are here to discuss are from a public point of view that by virtue of these scientific developments power has now become an interstate question. If in our interstate conflicts or national policies we are hindering the development of progress of so fundamental a thing, it is but right that we should consider the subject in all of its aspects and seek to remedy it.

There is a phase of this whole public relationship that seems to me to be slowly emerging, and that is that the United States will naturally divide itself into several power areas. For instance, the barren area of power consumption formed by the Adirondacks on the east and the character of natural resources along Mason and Dixon's line on the south create a natural district in the New England and Mid-Atlantic states. Another power district lies to the west of the Alleghanies and east of the Mississippi River. Still another district lies in the southeastern states, again in the southwestern states, and still another in the northwestern states. The problems in each of these power districts are essentially different as to the origins of power and the character of their industries, and are affected by the rate of probable industrial development in some states. And if we are to make rightful solution of national problems we should consider their development as essentially separate questions.

Albert Reid Ledoux

DR. Albert Reid Ledoux, who died on October 25, was an international figure in the mining and metallurgical industry. Since 1880 he had conducted a practice as consulting engineer, metallurgist, and assayer, and his integrity and intelligence gave him an outstanding reputation.

His serenity and sanity made him a dependable leader in engineering-society work. He was at one time president of the American Institute of Mining and Metallurgical Engineers and was the first president of the United Engineering Society when the joint building for the engineering societies became a reality. His guidance during the formative period was an important factor in the successful launching of a project that has been of incalculable value to the entire engineering profession.

Steinmetz

IT IS FORTUNATE that Steinmetz lived in an age when his remarkable genius could be utilized to its fullest extent. Steinmetz himself was fortunate in that he approached the great scientific problems when he was in his prime and was enabled to see his theoretical solutions of the problems put to practical use, so that during his own lifetime he could view the magnitude of his achievements and realize their importance to mankind.

His incomparable ability for mathematical analysis found an avenue for utilization in investigations of magnetism, alternating currents, radiation, thermodynamics, and illumination, and his contributions made possible the present state of the art of generation and transmission of electrical power. It is difficult to see how any other man could have possibly accomplished what he did. Prof. Harris J. Ryan, President of the American Institute of Electrical Engineers, expresses it in the following words:

Charles Proteus Steinmetz

> Through a period of years Dr. Steinmetz stood almost alone as the one electrical engineer in the world capable of defining and solving the many perplexing problems encountered for the understanding and improvement of the transformer, induction motor, alternator, and polyphase high-voltage system, the modern fundamental implements of the electrical engineer.

But in the story of Steinmetz there were many other things which contributed to the romantic tale of life and achievement. His orchids, his pet crows, his bicycle, his camp, his cooking, and his affection for his adopted sons are glimpses of a full and happy life. One paragraph in the introduction to his book on American and the New Epoch is especially revealing.

> When I landed at Castle Garden, from the steerage of a French liner, I had ten dollars and no job and could speak no English. Now, personally I have no fault to find with existing society; it has given me everything I wanted; I have been successful professionally, in engineering, and have every reason to be personally satisfied, and the only criticism which I can make is that I would far more enjoy my advantages if I knew that everybody else could enjoy the same.

Dr. Steinmetz, chief consulting engineer of the General Electric Company, died suddenly at his home in Schenectady, N. Y., October 26, from acute dilatation of the heart following chronic myocarditis, a weakening of the heart muscles, of many years' standing. He had returned from a trip to the Pacific Coast on October 13 and, an examination by his physician disclosing the fact that his heart action was unsteady, a complete rest was advised. But just as he was showing signs of improvement, he passed quietly away.

Charles Proteus Steinmetz, born April 9, 1865, in Breslau, Germany, was educated at the gymnasium (high school) and then at the University of Breslau, where he studied mathematics and astronomy, then physics and chemistry, and finally, for a short time, medicine and economics. Involved in the social democratic agitation against the government, he escaped to Switzerland in 1888, and there studied mechanical engineering at the Polytechnicum.

In 1889 he immigrated to America, and found a position with the Osterheld & Eickemeyer Manufacturing Company, first as draftsman, then as electrical engineer and designer, and finally in research work in charge of the Eickemeyer Laboratory, in New York.

With the absorption of the Eickemeyer-Field interests by the General Electric Company, Dr. Steinmetz joined the latter organization. Upon the transfer of the company's headquarters to Schenectady in the spring of 1894, Dr. Steinmetz organized and took charge of the calculation and design of the company's apparatus and of its research and development work.

For a number of years Dr. Steinmetz was professor of electrical engineering at Union College, and at the time of his demise was professor of electrophysics at Union University. During this period, however, he retained his connection with the General Electric Company as chief consulting engineer.

Dr. Steinmetz was past-president of the National Association of Corporation Schools, vice-president of the International Association of Municipal Electricians, past-president of the American Institute of Electrical Engineers, honorary member of the National Electric Light Association, past-president of the Illuminating Engineering Society, fellow of the American Association for the Advancement of Science, member of the (British) Institution of Electrical Engineers, member of The American Society of Mechanical Engineers, the Electrochemical Society, the Illuminating Engineering Society, the Physical Society, etc., etc. He had also served as president of the Common Council and twice as president of the Board of Education of the city of Schenectady.

A Search for Facts in Materials Handling

A CONFERENCE of the Materials Handling Division of the A.S.M.E. was held in the Engineering Societies Building on November 2 for the purpose of considering the future activities of the Division.

The formulas recently completed for computing the economies of labor-saving equipment were discussed and the value of such formulas to both the prospective user and the seller of equipment was emphasized. The report of the Formula Committee, which appeared in the September issue of Mechanical Engineering, has attracted wide attention and is being brought into use to secure an accurate measure of economies that may be obtained by installing labor-saving equipment. Facts will be of tremendous importance in developing the science of materials handling, and the Conference gave some attention to a program of research in this field, which would concentrate at first on one activity, such as industrial trucking. The use of the formula in obtaining comparable costs is to be secured by sending copies of it to manufacturers and users of materials-handling equipment, and inviting them to a conference during the Annual Meeting of the Society in December.

New Boiler Code Regulations for India

THE various states of India have for several years been engaged in the formation of a uniform Indian code of boiler regulations, to replace the several different codes that were in effect. According to recent advices, the new code has been declared effective and is being published, so that a warning is due to American exporters who may have occasion to consider deliveries of boilers or boiler appurtenances into that country. Although it will be sometime before a copy of the new Indian code can be obtained, information has been received that the new regulations become effective on January 1, 1924. A member of the Society located in India has advised that the new regulations differ quite materially from those which have previously been in force in any part of India. It is the hope that information may soon be received to permit a comparison of the new regulations with the A.S.M.E. Boiler Code.

Southern Sections Hold Regional Meeting at Chattanooga

Noteworthy Gathering at Which the Subjects of Welding, Power and Fuel, and Management Were Discussed

THE first Southern Regional Meeting of The American Society of Mechanical Engineers, held in Chattanooga, Tenn., October 23 and 24, was noteworthy for its interesting program bearing on the industrial problems of the South. The attendance of about 150 was made up of engineers from Atlanta, Birmingham, Knoxville, Greenville, Memphis, Nashville, and Cincinnati. A group of twenty students from the University of Tennessee at Knoxville attended in a body under the leadership of Dean Ferris. The Council of the Society was represented by Walter S. Finlay, Jr., of New York, Earl F. Scott of Atlanta, Henry M. Norris of Cincinnati, and Secretary Calvin W. Rice.

Technical sessions devoted to the subjects of welding, power and fuel, and management were presided over by Hon. Newell Sanders, Ex-U. S. Senator. The opening session of the meeting was devoted to welding. The first paper was presented by Fred E. Rogers[1] who dealt with the subject of welding in locomotive repair shops. Mr. Rogers told of a recent survey of locomotive-shop practice which showed over one hundred welding operations practiced in locomotive repair work. The complete paper gives a list of the parts that have actually been repaired. In discussing them Mr. Rogers dwelt at some length on the possibilities of repairing locomotive frames, cylinders, piston rods, pistons, wheel centers, tires, and steel tender transoms, in each case pointing out the difficulties to be overcome in producing a successful weld. Mr. Rogers stressed the extreme importance of competent supervision of welding in the railway repair shop. In all too many places the welders lead a somewhat happy-go-lucky existence, deciding themselves to a large degree what can be and what cannot be done with the torch. The result is that sometimes hot, disagreeable jobs are "passed up" as being impracticable, and parts are scrapped that could be profitably repaired. Apparatus sometimes is not kept in first-class working order. Pressure gages are allowed to go in disrepair, hose is used in bad condition, and welding tips are thrown away when a slight defect develops that might be easily corrected. Such conditions are due largely to the fact that many shop foremen having had no personal experience in welding have vague ideas of sound practice. They necessarily depend on their welders to devise ways and means for doing their work, and if the verdict in a particular case is for or against, they feel that they must necessarily accept it. This condition is rapidly improving due, of course, to the awakened interest in welding and also to the valuable service rendered by industrial engineers employed by the large concerns promoting the sale and use of welding equipment and supplies. Copies of Mr. Rogers' complete paper are available on application to the Secretary of the A.S.M.E.

S. W. Miller[2] treated the subject of Fusion Welding of Pressure Vessels and Pipe Lines. He pointed out that while the advantages of welded joints in low cost and absolute tightness had attracted considerable attention, there had been little attention paid to proper methods of design because the physical constants of welds had not been well known and because it had been too frequently assumed that if a certain design were suitable for riveting, for example, it must be equally good for welding.

Mr. Miller then discussed some common errors in design and showed how these errors might be avoided. In order to design intelligently, he said, the strength of welds and welded pieces must be known. In designing a riveted joint the tensile and compressive strengths of the sheet and the shearing and compressive strength of the rivets must be known. Also, there was always assumed reasonably good workmanship, such as reamed rivet holes, suitable-sized rivets properly driven, and accurate fitting up of the plates. Further, for important work the plate and rivet materials were controlled by carefully drawn specifications. To insure proper compliance with the various requirements, it had been found necessary to have inspectors watch the materials and workmanship, and suitable tests of the finished structure must be made.

Mr. Miller could not see any difference between the general requirements for fusion-welded pressure vessels and for riveted tanks, and he believed that a knowledge of weld strength and peculiarities, the use of proper materials, good inspection of the workmanship, and suitable tests of the completed article would result in a product that would be perfectly safe and of undoubted value. His treatment of pipe welding was confined to the subject of the circumferential seams joining lengths of pipe. He pointed out the advantages of welded joints for oil pipe lines, water lines, and steam pipes. In conclusion he proposed a specification for welding pipe. Mr. Miller's paper will appear in a future issue of MECHANICAL ENGINEERING.

The final paper of the session was presented by R. D. Reed,[3] who spoke on Arc Welding. Mr. Reed told how arc welding had been developed for production operations and showed many lantern slides of products that had been successfully manufactured by the arc welding process.

The program for the session on power and fuel was made up of two papers. The first was by Professors J. A. Switzer and W. L. Woolrich, of the University of Tennessee, who spoke on the Water, Coal, and Man Power of the Western Slope of the Southern Appalachian Mountains. The authors pointed out the natural advantages in the Southern Appalachian District of an abundance of coal of high quality, the availability of condensing water at low temperature, and a population of Anglo-Saxon strain, all these in addition to abundant rainfall and the resulting hydroelectric power possibilities. A paper on the Use of Pulverized Coal in Open-Furnaces was given by R. H. Lowndes, chief engineer of the Atlantic Steel Co. of Atlanta, who showed that pulverized fuel was not as suitable or as economical for open-hearth furnaces as natural gas or producer gas. Furnace repairs were much higher for pulverized-fuel-fired furnaces than for gas furnaces. Both of these papers appeared in the November issue of MECHANICAL ENGINEERING.

The Chattanooga Management Session was one of the series held during Management Week. The first speaker, H. G. Bryan,[4] outlined the growth of the hosiery industry in the South. He pointed out the great advantage of the small southern towns for hosiery mills in that they afford a plentiful supply of the right kind of labor. The large mills in which are incorporated finishing and dyeing plants are located in the larger towns with small branch mills in surrounding small towns which knit the cheaper goods and send them in to be finished at the central plant. This placing of the mills in small towns is a constructive step toward a reduction of the congestion in the larger cities.

The paper on the Measurement of Management by Prof. Joseph W. Roe, of New York University, was also presented, as was a discussion on Ratios for the Measurement of Management by Daniel E. Knowles of Chicago. The discussion at this session was most spirited. The matter of ratios for the measurement of management as presented by Professor Roe and Mr. Knowles elicited many questions as to the simple and practical ways of securing proper ratios for the guidance of manufacturing executives. The discussion in general emphasized the importance of considering the problems of any particular establishment in their relation to the problems of another plant or of the entire industry. Professor Roe's paper appeared in the November issue of MECHANICAL ENGINEERING. Mr. Knowles' paper will be abstracted later.

The entertainment features of the meeting consisted of a smoker, an excursion by special train to the Hales Bar Station of the Tennessee Power Company, and a visit to the Crane Company's enamelware plant.

E. C. Patterson was in charge of the general arrangements of the meeting and his committees were made up of the entire membership of the Chattanooga Section.

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[1] Air Reduction Sales Co., N. Y. Mem. A.S.M.E.

[2] Union Carbide & Carbon Research Laboratories. Mem. A.S.M.E.

[3] General Electric Co., Schenectady, N. Y.

[4] Gen'l Supt. Richmond Hosiery Mills, Richmond, Va.

Heat Transfer Through Wall Structures

ON October 22, 1923 representatives of the gypsum, brick, lime, and lumber industries met at the Bureau of Standards in Washington to discuss the Bureau's program of investigation into heat transfer through wall structures. At the present time the Bureau is securing results on the heat transfer through wall panels 6 ft. high by 3 ft. wide under dry conditions, with negligible wind pressure on two sides, and with temperature ranges from 0 deg. fahr. to 120 deg. fahr. About ten panels have been built representing typical walls used in the construction of small buildings.

Transportation and Progress

IN his valedictory as president of the National Machine Tool Builders' Association, Edward J. Kearney discussed transportation as a master key to progress. Mr. Kearney pointed out that the prosperity of the machinery industries depends upon general, mechanical, industrial, and agricultural development and prosperity, with an adequate transportation system as the master key. He specifically urged that every citizen should make a careful study of the transportation problem of the country. Every factor in economic progress, he said, points to greater production, greater wealth, and higher standards of living, implying greater consumption per capita, which necessitates more and better transportation.

Aeronautical Engineering at New York University

NEW YORK UNIVERSITY has inaugurated new courses in aeronautical engineering and industrial aviation in its department of mechanical engineering. The courses will cover aerodynamics, theory and practice of airplane design, the theory and practice of dirigible design, and the study of aircraft engines. Attention will also be given to air transportation for passengers and freight, air-mail operation, organization of landing fields, the technical and financial analysis of aviation projects, and to such applications of aviation as aerial photography, surveying, etc.

The course will be amplified by lectures by experts in the commercial-aviation field. Prof. Collins P. Bliss, head of the department of mechanical engineering, will direct the course, with Alexander Klemin, associate professor of aeronautic engineering in charge.

Progress Report of Engineering Foundation

THE following paragraphs are taken from the Progress Report which Director Alfred D. Flinn made at the October 18 meeting of the Engineering Foundation Board.

"The Committee on Concrete and Reinforced Concrete Arches, of the American Society of Civil Engineers, has organized and held one or more meetings. In response to a request from the society, \$500, half the appropriation for the current year, has been paid to the society. The Civil Engineers' Committee on Steel Column Research has been appointed recently and in response to a request from the society, payment of the appropriation for this year, \$1000, is being made to the society this week.

"Final payment of \$334 (total \$1000), to The American Society of Mechanical Engineers for its active committee studying the Properties of Steam will be made soon.

"Unfortunately, business conditions have prevented progress by the important Committee on Mining Methods. Consequently no payment has been made to the Mining Engineers.

"The Non-Ferrous Branch of the Fatigue of Metals Research has been financed for two years' work and payments are being made to University of Illinois through Engineering Foundation, as needed. Materials are being prepared and methods developed. Other branches of the project also are progressing.

"The Committee on Arch Dams has presented a commendable progress report. At suggestion of this Committee, the Director has conferred with Dr. Paul Heymans, of the Massachusetts Institute of Technology, about laboratory tests on small-scale models of dams made of celluloid, using the photoelastic method of studying stresses in engineering structures and machines. This method, developed by the General Electric Company, is being used in a study of pinions for electric-railway motors and in important designing for the Navy, in Dr. Heymans' laboratory. Dr. Heymans offers the use of laboratory and equipment, but it would be necessary for the Institute to ask reimbursement for cash expenditures for the tests, including services. A list of proposed tests has been received from the Committee. An estimate of cost has been requested from Dr. Heymans.

"Some work is being done on the Wood-Finishing Investigation including paint and varnish) at the Forest Products Laboratory. Dr. A. H. Sabin, of the Foundation's committee, incidentally to his business trips about the country, has done much to win interest and support for the project. Business depression in some branches has been a handicap.

"E. P. Polushkin recently presented a final report on his preliminary studies at the Columbia School of Mines of Internal Stresses in Metals. A few interesting facts, mostly negative, have been gained. Only \$420 was expended from appropriations totaling \$1100. Extensive and costly fundamental physical researches appear necessary before progress can be made along the lines on which he was working."

First 1923 Power Test Code Issued—Three to be Published in December

THE first of the 1923 Power Test Codes to be prepared for publication was the Code for Hydraulic Power Plants and Their Equipment, which made its appearance in October. This code is a revision of the Rules for Conducting Tests of Waterwheels which formed one of the group of ten test codes published by The American Society of Mechanical Engineers in 1915. A general revision of this 1915 series was authorized by the A.S.M.E. Council in 1917, and in the preparation of the Hydraulic Power Plant Code the American Society of Civil Engineers, the American Institute of Electrical Engineers, and the National Electric Light Association were invited to coöperate and to name three representatives on the joint committee. The completed code has passed through the required routine of public hearing and submission for comment. Students of hydroelectric development will be interested in comparing this new code with the old group of simple rules for conducting waterwheel tests. The personnel of Individual Committee (No. 18) on Hydraulic Power Plants is as follows: American Society of Civil Engineers: N. A. Carle, B. F. Groat, Clemens Herschel; American Institute of Electrical Engineers: H. W. Buck, H. S. Putnam, Philip Torchio; National Electric Light Association: C. M. Allen, Markham Cheever, J. A. Walls; American Society of Mechanical Engineers: J. L. Harper, R. D. Johnson, C. W. Larner, William F. Uhl (Chairman). The code is on sale to members of the coöperating organizations at a price of seventy cents per copy. To non-members the price is eighty cents.

Three test codes are in the hands of the printer for final publication and it is hoped that they will be ready for the comingA nnual Meeting. These are the sections on General Instructions, Definitions and Values, and Steam Engines. The first two mentioned are supplementary to all of the other codes and will be needed by those who purchase separate codes, as there is constant reference to them in the actual test codes.

Four additional codes are in the final stages of preparation, having gone through the process of public hearing. The comments and criticisms are now being reconciled by the Committee and publication will start in the near future. These four codes are the ones on Displacement Compressors and Blowers, Internal-Combustion Engines, Reciprocating Displacement Pumps, and Evaporating Apparatus.

At the coming Annual Meeting of the A.S.M.E. there will be a public hearing on the Test Codes for Locomotives and for Steam-Generating Units. Advance copies of these will be available to any member who desires to comment or criticize.

Altogether there will be nineteen sections in the complete volume of Power Test Codes, but as widely varying amounts of time and effort have been required in the preparation of the individual codes, they are being put into type and made available as fast as they are completed. The problem of publishing all of the codes in a single volume will be taken up later.

Engineering and Industrial Standardization

Standards for Round Unslotted Bolt Heads

THE first standard to be submitted to the Sponsors by the Sectional Committee on the Standardization of Bolt, Nut, and Rivet Proportions is the series of "carriage bolt" heads. The report was prepared by Sub-Committee No. 5, of which Mr. W. M. Horton is chairman, and it consists of standard dimensions for the six well-known round unslotted bolt heads. They are called (1) Common Carriage Bolt, (2) Button-Head Carriage Bolt, (3) Fin-Neck Carriage Bolt, (4) Ribbed Carriage Bolt, (5) Elevator Bolt, and (6) Step Bolt.

The Society of Automotive Engineers and The American Society of Mechanical Engineers are joint sponsors for this Sectional Committee, so this report having been approved by letter ballot of the full committee is now before these bodies for final approval and adoption. After such approval is received it will be transmitted to the American Engineering Standards Committee for approval as a "Tentative American Standard." The proposed standards are as follows:

Radius Under Head. Up to and including $^1/_2$ in. diameter, the radius of fillet under the head shall be $^1/_{32}$ in. Over $^1/_2$ in. diameter the radius of fillet under the head shall be $^1/_{16}$ in.

Tolerances. The tolerances on head diameters, up to and including $^1/_2$-in. bolts, shall be plus or minus 0.010 in. Over $^1/_2$-in. diameter this tolerance shall be plus or minus 0.015 in. The tolerances on squares shall be plus or miuus 0.010 in.

Formulas

The formulas used in computing the dimensions listed in the accompanying tables are based on the body dimensions of the bolt and are given below for the information of the manufacturer.

Carriage Bolts

Diameter of head $D = 2A + 1/16$ in.
Height of head $H = 1/2\,A$
Length of square $L = 1/2\,A + 3/32$ in.

Button-Head Carriage Bolts

Diameter of head $D = 2A + 1/16$ in.
Height of head $H = 1/2\,A$

Ribbed Carriage Bolts

Diameter of head $D = 2A + 1/16$ in.
Height of head $H = 1/2\,A$

Fin-Neck Carriage Bolts

Diameter of head $D = 2A + 3/32$ in
Height of head $H = 1/2\,A - 1/64$ in.
Width of fin $W = 1\text{-}1/2\,A + 1/16$ in.
Height of fin $X = 3/8\,A$ (To nearest 64th)

Elevator Bolts

Diameter of head $D = 3A + 1/8$ in.
Height of head $H = 1/2\,A$
Length of square $L = 1/2\,A + 3/32$ in.

Step Bolts

Diameter of head $D = 3A + 1/16$ in.
Height of head $H = 1/2\,A$
Length of square $L = 1/2\,A + 3/32$ in.

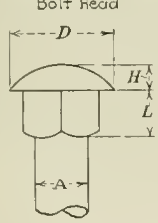
Standards for Steel Flanges for High-Pressures Definitely Planned

A COMPREHENSIVE PROGRAM of standardization of steel flanges and flanged fittings was launched at an open meeting of Sub-Committee No. 3 held in the rooms of The American Society of Mechanical Engineers, Friday, October 26. This Sub-Committee is a subdivision of the Sectional Committee on the Standardization of Pipe Flanges and Fittings which was organized under the procedure of the American Engineering Standards Committee. The three Sponsors for this project are: Committee of Manufacturers on Standardization of Fittings and Valves, the Heating and Piping Contractors National Association, and The American Society of Mechanical Engineers.

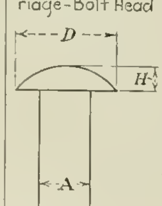
The informal conference on this subject which the Sponsors held on May 23 indicated such widespread interest in this subject that it was decided to organize a new sub-committee to develop standards for flanges to withstand high-superheat temperatures and pressures from 250 to 3200 lb. per sq. in. Prof. Collins P. Bliss of the Mechanical Engineering Department of New York University who is chairman of the Sectional Committee has decided to act also as chairman of this Sub-Committee. The other members of Sub-Committee No. 3 are Messrs. J. C. Bannister, C. W. E. Clarke, Sabin Crocker, R. D. Hall, H. E. Haller, J. A. Hance, C. H. Haupt, H. C. Heaton, J. S. Hess, F. Hodgkinson, D. S. Jacobus, O. F. Junggren, M. B. MacNeille, V. T. Malcolm, W. S. Morrison, W. A. Pope, G. W. Saathoff, J. R. Tanner and H. L. R. Whitney.

STANDARD DIMENSIONS FOR "CARRIAGE" BOLTS

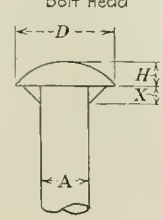
Common Carriage-Bolt Head



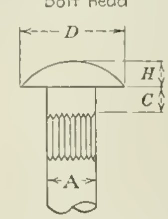
Button-Head Carriage-Bolt Head



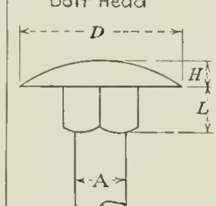
Fin-Neck Carriage-Bolt Head



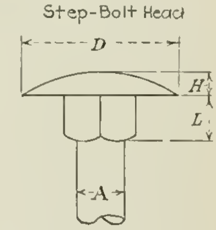
Ribbed Carriage-Bolt Head



Elevator-Bolt Head



Step-Bolt Head



	Common Carriage-Bolt Head			Button-Head Carriage-Bolt Head		Fin-Neck Carriage-Bolt Head				Ribbed Carriage-Bolt Head			Elevator-Bolt Head			Step-Bolt Head		
Diam. of Bolt *A*	Diameter *D*	Height *H*	Length of Square *L*	Diameter *D*	Height *H*	Diameter *D*	Height *H*	Length of Fin *X*	Width of Fin *W*	Diameter *D*	Height *H*	Depth of Rib Below Head *C*	Diameter *D*	Height *H*	Length of Square *L*	Diameter *D*	Height *H*	Length of Square *L*
3/16	7/16	3/32	3/16	7/16	3/32	15/32	5/64	5/64	3/8	7/16	3/32	1/8	11/16	3/32	3/16	5/8	3/32	3/16
1/4	9/16	1/8	7/32	9/16	1/8	19/32	7/64	3/32	7/16	9/16	1/8	1/8	7/8	1/8	7/32	13/16	1/8	7/32
5/16	11/16	5/32	1/4	11/16	5/32	23/32	9/64	1/8	17/32	11/16	5/32	3/16	1-1/16	5/32	1/4	1	5/32	1/4
3/8	13/16	3/16	9/32	13/16	3/16	27/32	11/64	9/64	5/8	13/16	3/16	3/16	1-1/4	3/16	9/32	1-3/16	3/16	9/32
7/16	15/16	7/32	5/16	15/16	7/32	31/32	13/64	11/64	23/32	15/16	7/32	1/4				1-3/8	7/32	5/16
1/2	1-1/16	1/4	11/32	1-1/16	1/4	1-3/32	15/64	3/16	13/16	1-1/16	1/4	1/4				1-9/16	1/4	11/32
9/16	1-3/16	9/32	3/8	1-3/16	9/32					1-3/16	9/32	5/16						
5/8	1-5/16	5/16	13/32	1-5/16	5/16					1-5/16	5/16	5/16						
3/4	1-9/16	3/8	15/32	1-9/16	3/8					1-9/16	3/8	3/8						
7/8	1-13/16	7/16	17/32	1-13/16	7/16					1-13/16	7/16	3/8						
1	2-1/16	1/2	19/32	2-1/16	1/2					2-1/16	1/2	3/8						

Mr. H. L. R. Whitney of the M. W. Kellogg Company was elected secretary. This list includes official representatives of the American Society for Testing Materials, Hydraulic Society, Power Piping Society, National Electric Light Association, the A.S.M.E. Boiler Code Committee, and the Sponsor Bodies. A few of the members of this sub-committee were appointed "at large" because of their special interest in and knowledge of this subject.

The open meeting held on October 26, which was also this Sub-Committee's organization meeting, was attended by 50 engineers, manufacturers of this product and users as well. The session lasted all day and the following important actions were taken:

Range of Pressures for Steel Flanges. The maximum steam pressures for which these standard flanges and flange fittings shall be developed are 250, 400, 600, 900, 1350, 2000, 3200 lb. per sq. in. The maximum temperature which they are to be designed to withstand was set at 750 deg. fahr.

250- and 400-lb. Steam Standards. These two steel standards are to have the same bolt circle and number of bolts as the present American cast-iron standard for 250 lb., except that the 2- and $2^1/_2$-in. sizes for the 400-lb. standard will have 8 bolts instead of 4. The other dimensions of these flanges are, however, to be modified to meet the conditions set for each.

600-lb. Steam Standard. The Sub-Committee further decided to use as the basis of the dimensions of this standard the bolt circle and the number of bolts of the present 800-lb. Hydraulic Standard developed by the A.S.M.E. Committee and published in December, 1918.

900-lb. Steam Standard. The basis for this new steam standard flange is to be the bolt circle and the number of bolts of the present 1200-lb. Hydraulic Standard developed by the A.S.M.E. Committee and published in December, 1918.

Standards for 1350-, 2000-, and 3200-lb. Steam Pressures. Flanges to withstand these pressures and the corresponding superheats are to be developed after the completion of the first four of the series. It will be noted that the seven maximum pressures selected form a geometrical series between the terms 250 and 3200.

Realizing the difficulty and inefficiency of twenty men trying to complete the details of these flange standards, Sub-Committee No. 3 elected two sub-committees. One of these headed by Mr. A. M. Houser as chairman, and Mr. H. L. R. Whitney as secretary, is to select from among the A.S.T.M. specifications the one best suited for this purpose and to set the limiting stresses and such tests as are considered to be necessary.

The second subdivision of "No. 3" is known as the "Working Committee." It has Mr. C. W. E. Clarke as its chairman and Mr. Whitney as secretary. The Working Committee has based the report of the Sub-Committee on the physical and chemical properties of cast steel. The Sub-Committee is to present its report consisting of proposed standard dimensions of flanges for 250, 400, 600 and 900 lb. per sq. in. pressure and 750 deg. fahr. to the Sectional Committee on the Standardization of Pipe Flanges at a meeting to be held in the Engineering Societies Building on Thursday, December 6.

International Standardization of Ball Bearings

The First International Ball-Bearing Conference, held in Zurich, Switzerland, on July 9, 1923, is of considerable general interest because it was the first meeting of delegates from the different countries at which an agreement was reached to propose definite international standards for a machine element.

The Sectional Committee on the Standardization of Ball Bearings was organized under the American Engineering Standards Committee in December, 1920, to bring about an international agreement. This Committee, sponsored by the Society of Automotive Engineers and The American Society of Mechanical Engineers, found that active work in this direction was being carried on only in Sweden and Germany, and at the start, therefore, limited its work to coöperation with these countries.

Early in 1922, Mr. O. R. Wikander as Official Delegate of the Sectional Committee on Ball Bearings visited Sweden and Germany. Several meetings were held in Berlin and Gothenburg, but it was impossible at that time to find common ground for the Swedes and the Germans.

Upon Mr. Wikander's return the Sectional Committee on the Standardization of Ball Bearings made a proposal which, however, was not successful in reconciling the differences between the German and Swedish plans. The object of Mr. Wikander's second trip to Europe in October, 1922, was to bring the three proposals into harmony. After conferences with the Standard Committees and delegates in Berlin and Stockholm, the first official International Ball-Bearing Conference was called. It met in Zurich on July 9, 1923, following the conference of secretaries of the national standardizing bodies of all countries. It was thus possible for the delegates to have the advantage of the coöperation of the director of the V.S.M. Bureau of Standards (Swiss), Mr. M. Zollinger, who presided at the meeting; Dr. P. G. Agnew, the American secretary; Mr. Erik Fornander, the Swedish secretary, and Mr. W. Hellmich, the German secretary. After ten hours' discussion of the various points under consideration, Mr. H. Törnebohm of Sweden, Mr. Max Gohlke of Germany, and Mr. Wikander reached an agreement on all questions.

A few weeks before the meeting in Zurich the American delegate visited London to enlist the coöperation of the British Engineering Standards Association and the British ball-bearing manufacturers; as a result Great Britain telegraphed the Conference that the Swedish proposal was preferred, but that the German proposal would be acceptable to them if necessary to obtain international agreement.

After the Conference Mr. Wikander visited the Italian Standards Committee, and was assured that Italy would probably be willing to accept proposals of the International Conference.

On July 10 and 11 the agreements reached were embodied in a report, and this was sent to all interested countries by the Swiss Bureau of Standards, which a few days before had been made international headquarters for all standardization questions. After another meeting in Berlin the final proposals were signed on October 5, 1923, and through the V.S.M. Bureau of Standards in Zurich they will now be submitted to the standardizing bodies of all countries for ratification or comments.

The negotiations outlined above convinced all the delegates of the impossibilities of carrying out standardization negotiations by correspondence, and of the great advantages of personal discussion of the pending questions. Practically all the real progress was made during the various personal meetings of the delegates. The experience gained during these negotiations has made Mr. Wikander rather optimistic as to the possibility of international standardization of other machine elements. One of the fundamental and perhaps the most important questions to be solved is the international establishment of preferred numbers, particularly of preferred diameters. This question appears to be even more important than the agreement on a universal system of measurement.

An Ericsson Tablet

A BRONZE TABLET commemorating the services to this country of Capt. John Ericsson is to be placed on the building at 95 Franklin Street, New York City, on the site of Captain Ericsson's residence from 1844 to 1864, where in 1861–62 he designed the *Monitor* and supervised its construction. The tablet is being erected by the families of Cornelius S. Bushnell, who obtained the contract for the vessel from the Government, and those of John F. Winslow and John A. Griswold, who with Mr. Bushnell financed its construction. The tables will bear bas reliefs of the four principals and side view of the vessel.

Corrections

In an editorial entitled "All in Six Weeks," published in the November issue of Mechanical Engineering, the Martin bombers were erroneously included in the list of large airplanes which had failed to give sufficient satisfaction to warrant the continuation of their building. The intention was to refer to Tarrant in England and not Martin in this country. Those who have followed the tests of sinking battleships in America need not be told that the Martin bombers proved a great success in their way instead of a failure.

In Fig. 4, page 640, of Mechanical Engineering for November, the scale for water required should range from 0 to 50 cu. ft. per sec. and not from 0 to 500 cu. ft. as printed.

The Internal-Combustion Engine

The Internal-Combustion Engine. By Harry R. Ricardo. Vol. 1: Slow-Speed Engines, 488 pp. Vol 2: High-Speed Engines, 373 pp. D. Van Nostrand & Co., New York, 1923. Cloth, 7 × 10 in., illus., $18.

THIS is one of the most complete investigations on the subject published within recent years and has been written by a man who has contributed extensively to the development of the art which he describes.

The first volume is devoted to slow-speed engines, covering the Diesel and related types, the gas engine, and the vaporizing oil engine. The chapters devoted to a discussion of the analysis of a modern gas engine and piston friction are of particular interest. The author cannot be said to be a very enthusiastic supporter of the Diesel engine. While recognizing its unquestionable value for certain uses, he says, for example, that the Admiralty was not wrong in not experimenting with Diesel engines for the propulsion of the latest types of battleships and battle cruisers in view of the limitations of the present-day types, and in view of their comparatively low commercial efficiency in a country, such as England, which is not oil-producing. It may be noticed, however, that the author does not go into the most recent developments in Diesel engines, in particular the compressorless types.

The second volume, devoted to the subject of high-speed engines, is of greater interest than the first. This may be said to be due mainly to the fact that the high-speed internal-combustion engine, unlike the low-speed type, has made truly amazing progress in the last ten years, largely under the influence of war requirements. As the author mentions, very soon after hostilities began the light, mobile, high-speed type of combustion engine applied to transport, aircraft, and later to tanks was destined to play a very important if not decisive part in the conduct of the war. As a result every effort was then made to concentrate all the available scientific talent on the high-speed engine. The campaign of intensive research which resulted from this sudden influx of scientific talent accompanied by almost inexhaustible funds for research has resulted in the production of light high-speed engines which, besides giving what a few years ago would have been considered an almost incredible power output in relation to their size and weight, can show as high an efficiency as that of the largest slow-speed engine. And what is perhaps even more important, the basic principles, both mechanical and thermodynamic, upon which the performance of such an engine depends, have been investigated in so complete and comprehensive a manner that the performance of any engine can now be gaged with accuracy from a study of the design alone; or, conversely, an engine can be designed to fulfill any specific requirement as to power output or efficiency with the same precision as in the case of a steam engine.

The author has taken an important part in this development and experimental work both during the war and since. For example, in all the engines used in the British tanks the Ricardo pistons were employed. He has therefore the necessary data and scientific equipment to present what may be termed the last word in high-speed internal-combustion engineering. The chapters of particular interest are those dealing with detonation, influence of form of combustion chamber on engine performance, mechanical design and details, piston design, and high-speed heavy-duty engines for tanks.

The work is beautifully printed and illustrated by a considerable number of finely reproduced halftones. In a way it is of particular interest to the American engineer, in that it tells about the best which has been achieved in England. On the other hand, however, it should be clearly understood that to all practical purposes the volumes deal exclusively with internal-combustion engineering as it has been developed and is today in England, with only very brief reference to French and German practice and extremely little to America. Thus, for example, in the chapter devoted to engines for road vehicles, of which probably more are built in the United States in a month than in Europe in a year, not a single American design is either described or illustrated. This makes the volumes somewhat incomplete in an important respect, but does not materially detract from their value as a clear, brief and generally reliable presentation of the subject by one who decidedly knew what he was writing about.

Aircraft Year Book. 1923. N. Y., Aeronautical Chamber of Commerce of America, Inc., 1923. Cloth, 6 × 9 in., 396 pp., illus., diagrams, tables, $3.

The volume is a summary of aeronautical events during the year, with especial reference to American activities. Technical commercial and military matters are reviewed and a great amount of useful and interesting information is presented. The book gives a convenient general view of present developments.

Aluminium Repairing. By William H. H. Platt. D. Van Nostrand Co., New York, 1922. Cloth, 5 × 7 in., 70 pp., diagrams, $1.50.

A practical manual that gives in detail methods which the author has used with success for repairing aluminum articles and for attaching aluminum to other metals.

Automatic Telephone Systems, Vol. 2; Auxiliary Services and Private and Branch Exchanges. By William Aitken. Ernest Benn, London, 1923. Cloth, 8 × 11 in., 227 pp., illus., diagrams, 35s.

The second volume of this important treatise is concerned with the various auxiliary services of automatic telephone plants. Some of the important questions treated are substation equipment for working extension lines, working party lines and small installations for subscribers' offices, branches, private installations, etc. An appendix supplements the first volume by describing several new pieces of apparatus. The work is very fully illustrated with diagrams of the circuits and is a thorough record of present British practice.

Capital's Duty to the Wage-Earner. By John Calder. Longmans, Green & Co., New York and London, 1923. Cloth, 5 × 8 in., 326 pp., tables, $2.25.

A study of the major industrial problems based upon an experience in industry extending over nearly forty years. There are chapters on the objections of labor to capitalism, on labor unionism, employers' associations, the "open" and the "closed" shop, shop organization, employees' representation, unemployment and similar questions, in which these matters are discussed and an attempt made to present practical answers. The author directs his book to the leaders in our industrial undertakings, to whom he appeals for improvement in the handling of the worker.

Chemical Resistance of Engineering Materials. By Marston Lovell Hamlin and Francis Mills Turner, Jr. Chemical Catalog Co., New York, 1923. Cloth, 6 × 9 in., 267 pp., diagrams, tables, $5.

This book is a collection of information about the behavior of metals, wood, cement, textiles and other structural and engineering materials, when exposed to the action of chemicals. Its purpose is to assist the engineer called upon to build chemical plants, in the selection of appropriate materials for piping, containers and other apparatus. Bibliographies are included, as well as a collection of useful tables.

Condensed Catalogues of Mechanical Equipment. 1923–24. American Society of Mechanical Engineers, New York, 1923. Flexible leather, 9 × 12 in., 678, pp. illus., $5.

The thirteenth edition of this reference book follows the lines of preceeding ones but is improved in detail and revised throughout. The Catalogue and Mechanical Equipment Directory sections have been enlarged.

This issue lists 3600 articles of equipment used by mechanical engineers and gives the names and addresses of 4400 firms that manufacture this equipment. Concise catalogue data from 393 of these firms are given, classified under general headings. The

directory of consulting engineers contains the names of 1000 practitioners, listed under 400 headings.

The volume is of convenient size and easy to handle. It will be useful to engineers, purchasing agents, and executives who wish information about sources of mechanical equipment, engineering materials, and other products used in power plants.

Crain's Market Data Book and Directory of Class, Trade and Technical Publications. 3d edition, 1923. G. D. Crain, Jr., Chicago, 1923. Cloth, 6 × 9 in., 497 pp., $5.

This book aims to present statistical and market data about the various industries, trades and professions, for the purpose of enabling an advertiser or merchant to obtain a picture of the field as a whole. An important feature of the book is the lists of publications covering each classification. These lists include all the important trade journals, and give the principal items of information desired by advertisers.

Elementary Principles of Lighting and Photometry. By John W. T. Walsh. E. P. Dutton & Co., New York, 1923. Cloth, 6 × 9 in., 220 pp., diagrams, $4.50.

This book aims to provide a simple guide to the solution of the problems most commonly met with in lighting engineering and to give both an explanation of the faults which experience has shown it necessary to avoid and of the means available for the attainment of a satisfactory result in any given case. The book is intended for electrical and gas engineers, architects, factory managers and for others who are called upon to consider matters of illumination, rather than for specialists in this field. The information is presented in readable form, requiring no previous knowledge of the subject.

Engineering Kinematics. By William G. Smith. McGraw-Hill Book Co., New York, 1923. Cloth, 6 × 9 in., 282 pp., illus., diagrams, tables, $3.

In this textbook the author, while giving first consideration to the fundamental principles of motion, its laws, its conversion and its transfer, has also given attention to the application of these principles to the design of agencies for transmission, transportation and production. He thus endeavors to relate the study to actual engineering problems and condition, so that the student's interest may be awakened by a knowledge of the practical applications of the science.

Engineering Non-Ferrous Metals and Alloys. By Leslie Aitchison and William R. Barclay. (Oxford technical publications.) Cloth, 6 × 9 in., 300 pp., illus., diagrams, tables, $7.

This book aims to supply engineers and manufacturers with accurate, useful information on non-ferrous metals and alloys. Throughout the maker and user are kept in mind, and the information selected and the method of presentation are those that fit his needs.

The first section of the book deals with the non-ferrous metals and alloys generally. The reasons for their use in engineering, their constitution, casting, working, heat treatment, mechanical properties and the methods of testing them are described and explained. Section two takes up individual metals and alloys in some detail. The alloys of copper, aluminium and of nickel, together with some miscellaneous alloys, are included. The final chapter discusses the choice and specification of an alloy.

English for Engineers. By S. A. Harbarger. McGraw-Hill Book Co., New York, 1923. Cloth, 5 × 7 in., 266 pp., $2.

The object of this textbook has been to make the study of English definite for the engineering student, and to stimulate his interest in a brief but comprehensive survey of the immediate uses to which English may be put by the engineer. It is intended to acquaint him with the sources for the study of English both for professional and cultural needs and interests.

Professor Harbarger discusses various practical matters of ordinary professional life, such as letters of application, order, inquiry and instruction; sales letters, dictation, the composition of technical articles and reports; and cultural reading. References for collateral reading are given in each chapter.

Foundry Work. By R. E. Wendt. McGraw-Hill Book Co., New York, 1923. Cloth, 5 × 8 in., 206 pp., illus., tables, $2.

A textbook covering the general principles of foundry work, instruction in molding and core making, and in mixing and melting metals. Intended for use in colleges and by apprentices. The author is head instructor in foundry practice in Purdue University, and the book is based on his experience in teaching the subject there.

Friction. By T. E. Stanton. Longmans, Green & Co., New York, 1923. Cloth, 6 × 9 in., 183 pp., diagrams, tables, $4.20.

In the past it has been customary to treat the various phenomena which can be grouped under the term "friction" more with reference to the particular branch of mechanics with which the frictional effect is associated than as intimately related manifestations of certain properties of matter. In the present book the author has adopted the view that friction is an essentially molecular phenomenon, best studied as a distinct branch of mechanics; and to facilitate this has collected in a single volume the results of modern investigations into the nature and laws of friction. The book is intended for engineers and research workers in engineering and the allied sciences.

Fundamentals of Welding, Gas, Arc and Thermit. By James W. Owens. Penton Publishing Co., Cleveland, Ohio, 1923. Cloth with leather back and corners, 6 × 9 in., 659 pp., illus., $10.

A number of years ago, the Bureau of Construction and Repair of the Navy undertook a special study of the art of fusion welding. With this work Mr. Owens has been connected from the beginning and in charge of it for some years. This book, based on his experience, also makes use, by permission, of the results obtained by the investigations of the Navy and includes the matter previously published confidentially by it. The book is a complete practical manual on its subject. It sets forth the relative merits of different methods and their adaptability to different materials, the apparatus which is used, the preparation of the joints, the methods of welding, inspection, etc. Standard welding specifications are included.

"Hutte," des Ingenieurs Taschenbuch. By Akademischen Verein Hütte, Berlin. Vol. 2; second edition. Wilhelm Ernst & Sohn, Berlin. 1923. Cloth, 5 × 7 in., 1288 pp., illus., tables, $2.

The second volume of this new edition covers the important subjects of Prime Movers, Measurements, Machinery, Shipbuilding and Marine Engines, Automobile Construction, Lighting and Electrical Engineering. It has been partly rewritten and partly revised, over 200 pages having been added. The principal additions have to do with Boilers, Engines, Steam Turbines, Internal-Combustion Engines, Hoisting Machinery, and Electricity. Each section is the work of a group of specialists.

Internal-Combustion Engines, Theory and Design. By Robert L. Streeter. Second edition. McGraw-Hill Book Co., New York, 1923. Cloth, 6 × 9 in., 443 pp., illus., diagrams, $4.

This edition has been thoroughly revised by the author, with the assistance of several other engineers who have contributed chapters on their specialties. The book is thus brought in line with present practice in design and construction and covers small gas and gasoline engines, automobile engines, large gas engines and oil engines. A chapter is devoted to the Humphrey gas pump.

Die Konstruktionsstahle und Ihre Warmebehandlung. By Rudolf Schafer. Julius Springer, Berlin, 1923. Cloth, 5 × 8 in., 370 pp., illus., diagrams, tables, $3.60.

This book is a clearly written account of the varieties of iron and steel used in machine and building construction, and of the effects of different methods of heat-treating upon their qualities. The author has tried to condense the voluminous literature into a book of convenient size and has had in mind the needs of designers and manufacturers of machinery and of dealers rather than those of metallurgists. Alloy steels are discussed.

Mathematical Theory of Relativity. By A. Kopff. E. P. Dutton & Co., New York, 1923. Cloth, 5 × 8 in., 214 pp., $3.20.

The present introduction to the theory of relativity as expounded by Einstein arose out of a series of lectures delivered at Heidel-

berg in 1919–20. The object of this work is to reproduce in the simplest possible terms the investigations that have been conducted into the foundations of this theory, and as a consequence the treatment is necessarily of a mathematical nature. The mathematical and physical equipment required for study of the book is approximately that which is acquired during the first few terms of a college course.

Mechanics of Machinery: Mechanism. By Robert C. H. Heck. McGraw-Hill Book Co., New York, 1923. Cloth, 6 × 9 in., 508 pp. diagrams, $5.

The purpose of this work on the mechanics of machines is to cover the whole field of motions and forces in machines, in a manner suitable for study and teaching and as a related and consistent whole instead of as scattered isolated branches. The present volume treats chiefly of mechanism. The material presented is arranged according to the problems in mechanism or mechanics which it presents, rather than according to kinds of machines. The ground is covered with sufficient completeness to make the book a useful reference treatise as well as a textbook.

Les Méthodes Modernes D'Organisation Industrielle. By L. Benoist. Gauthier-Villars et Cie., Paris, 1923. Paper, 6 × 9 in., 208 pp., tables, 18 fr.

An introduction to management intended for young engineers. The book opens with a general survey of modern life, its activities and objects. This is followed by an account of modern methods of organization in the office and the shop. The final section deals with shop practice and includes many tables showing the time required for tool and hand operations in turning, fitting, assembling, etc.

Modern Gas Producers. By N. E. Rambush. Benn Bros., London, 1923. Cloth, 7 × 10 in., 545 pp., illus., diagrams, tables, 55s.

An important treatise on its subject. The special problems that arise in the manufacture of producer gas and the design of producer-gas plants are treated in full detail and the specific features of each design that has been built and operated have been set forth. The book is very fully illustrated with drawings and photographs.

Oil Flow—Viscosity and Heat Transfer. By R. S. Danforth. R. S. Danforth, San Francisco, 1923. Paper, 6 × 9 in., 16 pp., charts, $2.

The charts in this pamphlet show the average values of the viscosities of crude and fuel oils at various temperatures. They include data on oils from various sections of North America and are intended for use when tests on the particular oil to be pumped are not available. The temperature-drop charts, which are mainly of use in long pipe lines, take into consideration turbulence and pipe diameter, and give satisfactory results when used to design lines for a given capacity of a given oil or for forecasting the results of changing the operating conditions in existing lines. Charts are given for lines exposed to soil, air, or water, and for insulated lines.

Practical Applications of X-Rays. By G. W. C. Kaye. E. P. Dutton & Co., New York, 1923. Cloth, 6 × 9 in., 135 pp., illus., diagrams, tables, $5.

In this book the author, who is head of the radiology department of the National Physical Laboratory, confines himself to the practical uses of X-rays in science and industry. A brief introductory chapter on the nature and generation of X-rays is followed by chapters on X-ray bulbs, high potential generators and methods for the measurement of X-rays. Chapter five discusses the medical applications of X-rays in diagnosis and the treatment of disease. Chapter six calls attention to industrial applications, such as the examination of metals for flaws, of explosives and ammunition, of timber, aircraft, welds, rubber and glass, the investigation of old paintings, etc.

La Radiotéléphonie. By Carlo Toché. Second edition. Gauthier-Villars et Cie., Paris, 1923. Paper, 6 × 10 in., 120 pp., illus., diagrams, 10 fr.

The aim of this book is to give the general public with no special scientific knowledge a clear idea of the principles of radiotelephony, of its apparatus and of the methods of building and operating receiving stations. A chapter is devoted to the applications of telephony and its future possibilities.

Regulation and the Management of Public Utilities. By Charles Stillman Morgan. Houghton Mifflin Co., Boston and New York, 1923. Cloth, 5 × 8 in., 362 pp., tables, $2.50.

This book is devoted to a study of the management of a regulated industry. Its principal objects are the determination of the efficiency with which this industry is conducted and of the causes accounting for the degree of efficiency attained, as well as the critical examination of various measures that are used, or have been proposed, for the purpose of eliminating certain latent germs of inefficiency which the industry itself and the regulation to which it is subjected may be said to produce. The analysis is confined to the present day and the immediate future, there being no attempt to review the history of public regulation nor to outline its probable future course. The study is limited to the economic aspects of the problem and to "public utilities" in the narrow sense, railroads and other interstate carriers being excluded from it.

Der Schiffsmaschinenbau. Vol. I. By Gustav Bauer. R. Oldenbourg, Munich and Berlin, 1923. Paper, 8 × 11 in., 157 pp., illus., diagrams, $7.25.

Some years ago Dr. Bauer published a book entitled Berechnung und Konstruktion der Schiffsmaschinen und Kessel; and also, with Dr. Lasche, one upon marine turbines. The present work is intended as a revised edition of those two books but is considerably expanded, especially by the addition of a volume on marine internal-combustion engines. The first volume is devoted to reciprocating steam engines and screw propellers. The theory is presented thoroughly, yet concisely. Great attention is given to practical design and construction of engines, condensing apparatus and screws, the subjects being discussed in detail and illustrated with many examples. An appendix, 150 pages long, discusses many important theoretical considerations, such as the flow of heat in cylinder walls, heat regeneration, critical speeds, the influence of the depth of water on the speed of ships, etc.

Succeeding volumes will take up turbines, boilers, auxiliary machinery, and internal-combustion engines. The book is well printed on good paper. It should be of interest to marine engineers and designers of steam engines.

Steel Thermal Treatment. By John W. Urquhart. D. Van Nostrand Co., New York, 1922. Cloth, 6 × 9 in., 336 pp., illus., tables, $8.

Having been engaged for many years in the production of machinery and tools, the author has been under the necessity of putting to practical use all the recently introduced processes for the heat treatment of steel. This book describes the apparatus used for heat treatment, and the processes and their adaptation to various purposes. The physical and chemical phenomena that occur are explained and an endeavor is made to coördinate the work of the laboratory and the factory.

Tabellen und Diagramme fur Wasserdampf. By Oscar Knoblauch, E. Raisch and H. Hausen. R. Oldenbourg, München and Berlin, 1923. Paper, 8 × 11 in., 32 pp., diagrams, tables, $0.50.

This pamphlet presents the results of the measurements of the specific heat of steam made during the past twenty years at the Laboratory of Technical Physics in Munich. Their importance consists not only in the new data upon the characteristic changes in the specific heat of steam with the pressure and temperature, but also in the possibility of deriving the other properties of steam numerically by calculation from the specific heat and some factors, and thus preparing steam tables by a new and more convenient method. The principal tables give the usual thermodynamic constants of steam, one for temperatures from 5 to 275 deg. cent., at five-degree intervals, the other for pressures from 0.02 to 60 kg. per sq. cm. Other useful tables and charts are also included in this pamphlet.

Wood Pattern-Making. By Herbert J. McCaslin. McGraw-Hill Book Co., New York, 1923. Cloth, 5 × 8 in., 296 pp., illus, $2.25.

For the student who desires to follow the occupation of pattern-making or to familiarize himself with the principles of that art, this book gives a clear account of the principles of molding and of pattern construction in the shape of a series of problems arranged in a progressive course. Very definite instructions as to the order of operations are given for each exercise.

THE ENGINEERING INDEX

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Exigencies of publication make it necessary to put the main body of The Engineering Index (p. 143-EI of the advertising section) into type considerably in advance of the date of issue of "Mechanical Engineering." To bring this service more nearly up to date is the purpose of this supplementary page of items covering the more important articles appearing in journals received up to the third day prior to going to press.

AIRPLANES

Wren Light. The "Wren" Light Aeroplane. Engineering, vol. 116, no. 3017, Oct. 26, 1923, pp. 526–528, 8 figs. partly on p. 530. Details of design of cantilever monoplane which tied for two prizes awarded for maximum distance flown per gal. of gasoline, at Lympne competition; important feature of design is low weight of main components.

ALLOY STEELS

Temperature and Impact Value. Temperature and Charpy Impact Value, F. C. Langenberg. Iron Age, vol.112, no. 18, Nov. 1, 1923, pp. 1170–1172, 6 figs. Investigation of influence between these elements in group of steels of varying composition, including stainless steels. Paper before Am. Iron & Steel Inst. See also Iron Trade Rev., vol. 73, no. 17, Oct. 25, 1923, pp. 1174–1179, 5 figs.

CARBURETORS

Plain-Tube, Fixed-Jet. Stewart-Warner Starts Production on New Carbureter. Automotive Industries, vol. 49, no. 17, Oct. 25, 1923, pp. 828–829, 3 figs. Die-cast body, throttle at air inlet, arrangement of jet to insure good atomization, and rugged float mechanism are chief features; design is such as to permit use of system of unit assemblies in production; manufacturing costs lower as result.

CASE-HARDENING

Gray Cast Iron. Case Hardening and Other Heat Treatment as Applied to Gray Cast Iron, H. B. Knowlton. Am. Soc. for Steel Treating—Trans., vol. 4, no. 4, Oct. 1923, pp. 494–506, 30 figs. Experiments conducted in heat-treating gray cast iron; it was found that under certain conditions gray cast iron could be made much tougher in center and at same time be given hard surface.

CONDENSERS, STEAM

Hick-Breguet Type. Condensing Plant for 20,000-Kw. Turbine at Shangai. Engineering, vol. 116, no. 3016, Oct. 19, 1923, pp. 494–496, 9 figs. partly on p. 498. Describes surface-condensing plant of Hick-Breguet type designed to condense 239,000 lb. of exhaust steam per hr. and maintain vacuum of 28 in. at exhaust inlet to condenser.

ELECTRIC WELDING, ARC

Cast Iron. Arc-welding Cast Iron Without Preheating, J. P. Kryza. Machy. (N. Y.), vol. 30, no. 3, Nov. 1923, pp. 199–200, 1 fig. In method developed by Super Arc Welding Machine Co., Detroit, Mich., neither preheating nor reheating is required, because surface welded is only slightly fused.

FORGINGS

Steel. Recent Developments in Steel Forgings, John L. Cox. Iron Age, vol. 112, no. 18, Nov. 1, 1923, pp. 1175–1177. Developments in alloy steel forgings; hardened steel rolls; crankshafts; large hollow drawn forgings; large solid forgings. See also Iron Trade Rev., vol. 73, no. 18, Nov. 1, 1923, pp. 1233–1236 and 1239, 7 figs. (Abstract.) Paper read before Am. Iron & Steel Inst.

GEAR CUTTING

Hobbing, Spiral, Bevel Gears. Hobbing, Spiral, Bevel Gears, Nikola Trbojevich. Machy. (N. Y.), vol. 30, no. 3, Nov. 1923, pp. 165–176, 16 figs. New development in gear-cutting practice that makes it possible to produce accurate spiral bevel gears by hobbing process.

GEARS

Standardization. Progress in Gear Standardization. Am. Mach., vol. 59, no. 19, Nov. 8, 1923, p. 669. Résumé of work of subcommittee of Am. Gear Mfrs. Assn. and report of action taken at meeting, Oct. 1923. See also Iron Age, vol. 112, no. 18, Nov. 1, 1923, pp. 1182–1183 and 1217–1218.

GRINDING

Production. The Elements of Production Grinding, Ellsworth Sheldon. Am. Mach., vol. 59, nos. 2, 4, 6, 8, 10 and 12, July 12, 26, Aug. 9, 23, Sept. 6 and 20, 1923, pp. 37–41, 131–133, 209–211, 277–280, 373–376, and 443–444, 42 figs. July 12: Early practice; artificial abrasives; development of production grinding. May 26: Manufacture of wheels; modified abrasives; vitrified, silicate and elastic wheels; grains and grades. Aug. 9: Selection of grinding wheels; wheel and work speeds. Aug. 23: Location and care of machine; vibration elimination; balancing, dressing and truing of wheels; causes of loading and glazing; use of grinding compounds. Sept. 6: Cause and remedy of chattering; use of steadyrests; preparing work for grinding machine. Sept. 20: Two main classes of grinding machines.

GRINDING MACHINES

Gear. Spur-Gear Grinding Machines. Iron Age, vol. 112, no. 19, Nov. 8, 1923, pp. 1237–1238, 5 figs. New unit for grinding involute teeth on production basis.

Surface. Automatic Tilting Work Table Chief Feature of New Surface Grinder. Automotive Industries, vol. 49, no. 17, Oct. 25, 1923, pp. 850–851, 2 figs. Osterholm automatic surface grinder is capable of handling wide range of production; will grind plane surfaces such as oil pans and cylinder heads with maximum dimensions of 10 in. by 40 in.

HANDLING MATERIALS

Factories. Automatic Conveying in Material Handling, L. S. Love. Iron Age, vol. 112, no. 17, Oct. 25, 1923, pp. 1105–1109, 12 figs. Vertical units and various types of horizontal conveyors in intensive use in National Cash Register works.

HEAT TRANSMISSION

Laws. The Laws of Heat Transfer. Engineering, vol. 116, nos. 3001, 3003 and 3005, July 6, 20 and Aug. 3, 1923, pp. 1–3, 69–70 and 131–132, 4 figs. Study based on Webster's experiments to determine laws of heat transfer between hot tube and fluid traversing it; deduces from Webster's experiments coefficient with which "ideal" thickness of film calculated must be multiplied in order to get actual film thickness.

HYDRAULIC TURBINES

Investigations. Water Turbine Investigations, Hubert Mawson. Engineering, vol. 114, no. 3017, Oct. 26, 1923, pp. 539–542, 14 figs. Analytical and experimental investigations. (Abstract.) Paper read before Brit. Assn.

HYDROELECTRIC PLANTS

Generators, Minimum Number Required. Minimum Number of Hydro-Electric Units to Have in Service, Ralph Brown. Power, vol. 58, no. 19, Nov. 6, 1923, pp. 722–723, 2 figs. Factors that determine number of machines to have in service; how loading of machines affects efficiency of plant; methods of supplying wattless current to system.

INDUSTRIAL MANAGEMENT

Auditing. A Management and Methods Audit, Frederick A. Waldron. Management & Administration, vol. 6, no. 4, Oct. 1923, pp. 479–481. Author advocates periodical inspection of organization and means through which money is spent.

Pay-Roll System. A Daily Balanced Pay-roll System, Lewis J. Brown. Management & Administration, vol. 6, no. 4, Oct. 1923, pp. 445–452, 3 figs. Describes system in use for past two years in plant of American Rolling Mill Co., and summarizes objects which have been obtained thereby.

Planning and Cost Control. Planning—Its Place in Cost Control, R. W. Darnell. Management & Administration, vol. 6, no. 5, Nov. 1923, pp. 605–610, 14 figs. Gives examples of piece-part, roughstores and assembly specification records; duties of planning department; departmental recapitulation of machine hours; planning as related to cost accounting.

LUBRICATION

Theory and Practice. Developments in Lubrication Theory and Practice, P. M. Heldt. Automotive. Industries, vol. 49, nos. 12, 15, 16 and 17, Sept. 20, Oct. 11, 18 and 25, 1923, pp. 573–575, 735–739, 800–801 and 842–844, 7 figs. Sept. 20: Laws of bearing and dry friction when loads are high; experiments on grooved and ungrooved bearings. Oct. 11: Effect of surface velocity, temperature, character of material and of lubricant on frictional loss. Oct. 18: Use of oil grooves, functions, advantages and disadvantages. Oct. 25: Definition of "oiliness;" theory of colloids; test methods.

MOTOR TRUCKS

Loading and Unloading Device for. Loading and Unloading Device for Motor Vehicles. Engineering, vol. 116, no. 3016, Oct. 19, 1923, pp. 490–491, 11 figs. Describes device developed in Switzerland, aim of which is to build up material, whether it be machinery, cases, packages or loose waste substances, on platforms or in standard container, back lorry to load and raise latter by means of haulage gear which is part of equipment.

OFFICE MANAGEMENT

Rating Plan. A Practical Plan for Rating the Efficiency of an Office Organization, W. H. Leffingwell. Taylor Soc.—Bul., vol. 8, no. 5, Oct. 1923, pp. 178–188, 1 fig. Describes examination and rating plan as applied to office organization; requirements of plan of rating; divisions and subdivisions of plan; its value and method of application.

OIL ENGINES

Overheating Pistons. Overheating of Oil-Engine Pistons, H. F. Shepherd. Power, vol. 58, no. 17, Oct. 23, 1923, pp. 649–650, 2 figs. Heating of air charge, avoidance of piston heating; author points out that, with properly cooled pistons and separate scavenge pumps, much of mystery that has made it impossible to design two-stroke-cycle solid-injection engines of semi-Diesel type with exactly same factors regardless of size would disappear.

OIL FUEL

Burners. The Correct Method of Using Fuel Oil, H. A. Anderson. Forging—Stamping—Heat Treating, vol. 9, no. 10, Oct. 1923, pp. 437–440. Discusses various types of fuel-oil burners and their uses as applied to forging and heat-treating furnaces; efficiencies compared.

OXY-ACETYLENE WELDING

Metallography of Welds. Metallography and Testing of Oxyacetylene Welds, J. R. Dawson. Am. Soc. for Steel Treating—Trans., vol. 4, no. 4, Oct. 1923, pp. 467–487, 18 figs. Deals with application of oxy-acetylene welding to various classes of steel and to cast iron; includes photographs illustrating effect of process on structure of metals that are welded; physical properties of welded metals; plea is made for application of principles of heat treating to welding problems.

Railway Car Shops. Oxy-acetylene Welding in Railroad Car Shops. Machy. (N. Y.), vol. 30, no. 3, Nov. 1923, pp. 177–180, 9 figs. Application of oxy-acetylene welding and cutting process to production, repair and plant maintenance.

PUMPS, CENTRIFUGAL

Curves. Charactristic Curves of Centrifugal Pumps, Russel K. Annis. Power, vol. 58, no. 17, Oct. 23, 1923, pp. 653–655, 11 figs. Comparison of flat and drooping curves; boiler-feed pumps, it is claimed, should have flat curve; large capacity desirable in circulating pumps.

PYROMETERS

Selection and Care. The Selection and Care of Pyrometers, J. W. Conzelman. Power, vol. 58, no. 17, Oct. 23, 1923, pp. 644–646. Explains fundamental principles underlying operation of four main types of electrical pyrometer (thermocouple, resistance, radiation and optical), and gives practical pointers on selection and care of thermocouple instruments, including detailed instructions for making, calibrating and installing thermocouples.

SEPARATORS

Coal. Recovering Fuel from Boiler Ash and Clinker, C. H. S. Tupholme. Power Plant Eng., vol. 27, no. 21, Nov. 1, 1923, pp. 1075–1079, 9 figs. Novel European schemes for recovering fuel from refuse; Waller, Blackett, Weber; and Columbus washers; Belgian washer employing pulsating piston; magnetic process used in Germany.

STEAM-ELECTRIC PLANTS

Belfast, Ireland. The New Belfast Power Station. Engineer, vol. 136, no. 3538, Oct. 19, 1923, pp. 415–418, 10 figs. Present capacity is 24,000 kw.; details of layout and equipment.

Manchester, England. The New Barton Power Station of the Manchester Corporation. Engineer, vol. 136, no. 3537, Oct. 12, 1923, pp. 391–394, 11 figs. partly on p. 396. General layout; coaling arrangements; boiler-house plant; turbine house; circulating water system; switch house; transmission and distribution; feeder cables.

Operating Results. The Operating Results of Blackburn East Power Station (England). Engineering, vol. 116, no. 3017, Oct. 26, 1923, pp. 515–517, 12 figs. partly on supp. plates. Outline of Equipment and data on performance of station.

STEAM POWER PLANTS

Durant Motors, Elizabeth, N. J. Power Plant of the Durant Motors, Elizabeth, N. J. Power, vol. 58, no. 17, Oct. 23, 1923, pp. 638–643, 11 figs. Plant of 8750 kva. capacity designed especially for industrial service; boiler plant contains six 6020-sq. ft. water-tube boilers fired with traveling-grate stokers; turbine-driven forced-draft fans installed in front of boilers; steam for process and heating supplied by exhaust from steam-driven auxiliaries and extraction from main units.

STEEL, HEAT TREATMENT OF

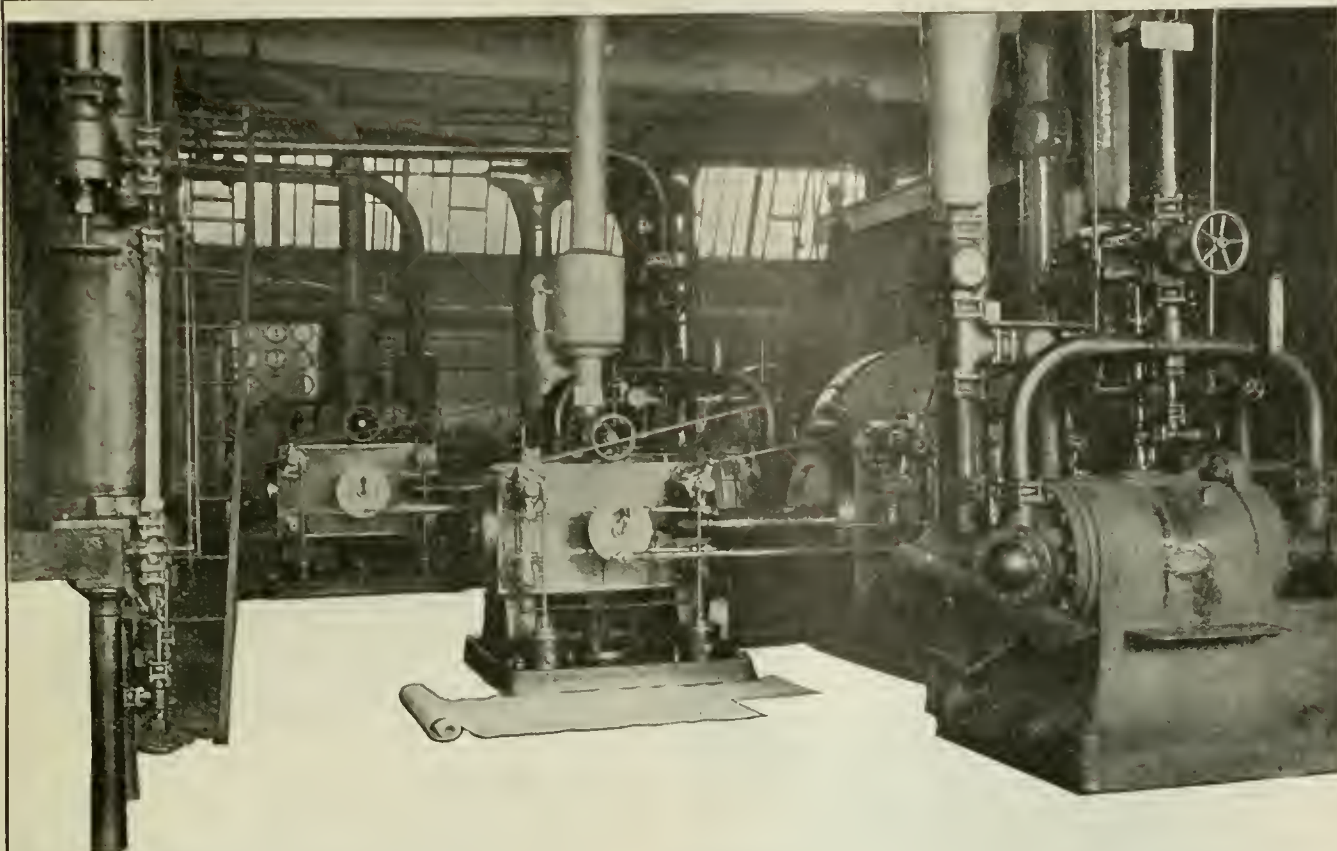
Quenching. The Theory in Quenching Steels, Kotaro Honda. Am. Soc. for Steel Treating—Trans., vol. 4, no. 4, Oct. 1923, pp. 450–466, 11 figs. Review of theory of mechanism and principles involved in quenching of steels; study of quenching cracks and their causes; author develops theory based upon experimental data and suggests remedy for eliminating quenching cracks.

STEEL WORKS

Electric Drives. Adjustable Speed Motor Drives, R. W. Davis. Assn. Iron & Steel Elec. Engrs., vol. 5, no. 10, Oct. 1923, pp. 601–615 and (discussion) 616–619, 5 figs. Discusses four types of drives used in steel mills, namely, direct-current, Sherbius or a.c. commutator, frequency converter, and Kraemer or rotary converter, and points out advantages of each.

STRESSES

Graphical Determination. On the Graphical Determination of Stress from Photo-Elastic Observations, L. N. G. Filon. Engineering, vol. 116, no. 3016, Oct. 19, 1923, pp. 511–512, 2 figs. Describes method of deriving stresses in transparent plate directly from isoclinic and isochromatic lines, and gives actual example of its application. Contribution to report of Committee of Brit. Assn. on complex stress distributions.



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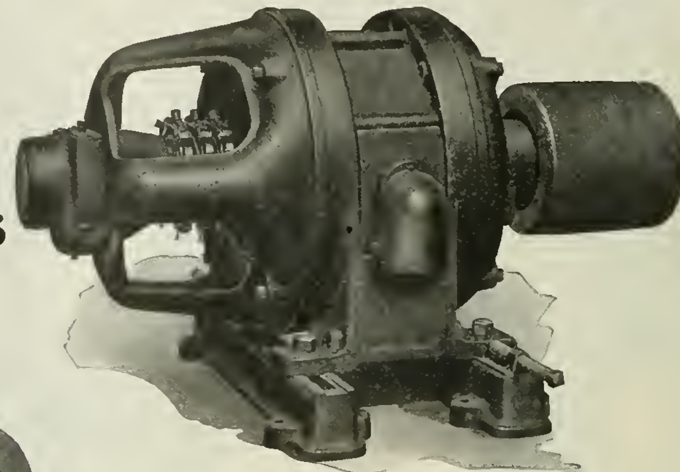

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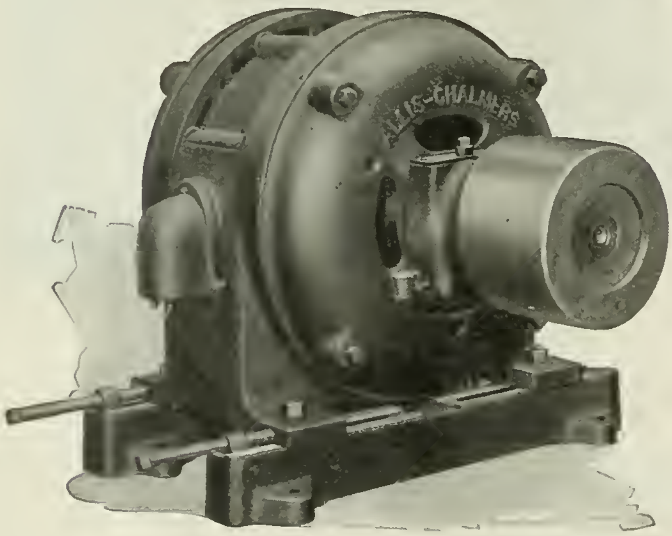

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Designed with exceeding ruggedness, cast steel in place of cast iron being a prominent feature.

Method of ventilation is very effective, resulting in even cooling and avoiding of "hot spots."

Bearings are of liberal design with spacious oil-wells.

Insulation is of highest grade, stator being treated with baked-on insulating varnish making the whole structure dust and moisture proof.

Motors are for floor or ceiling mounting being provided with very stiff and substantial rails.

Conduit terminal boxes are regular equipment.

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Gas Engines
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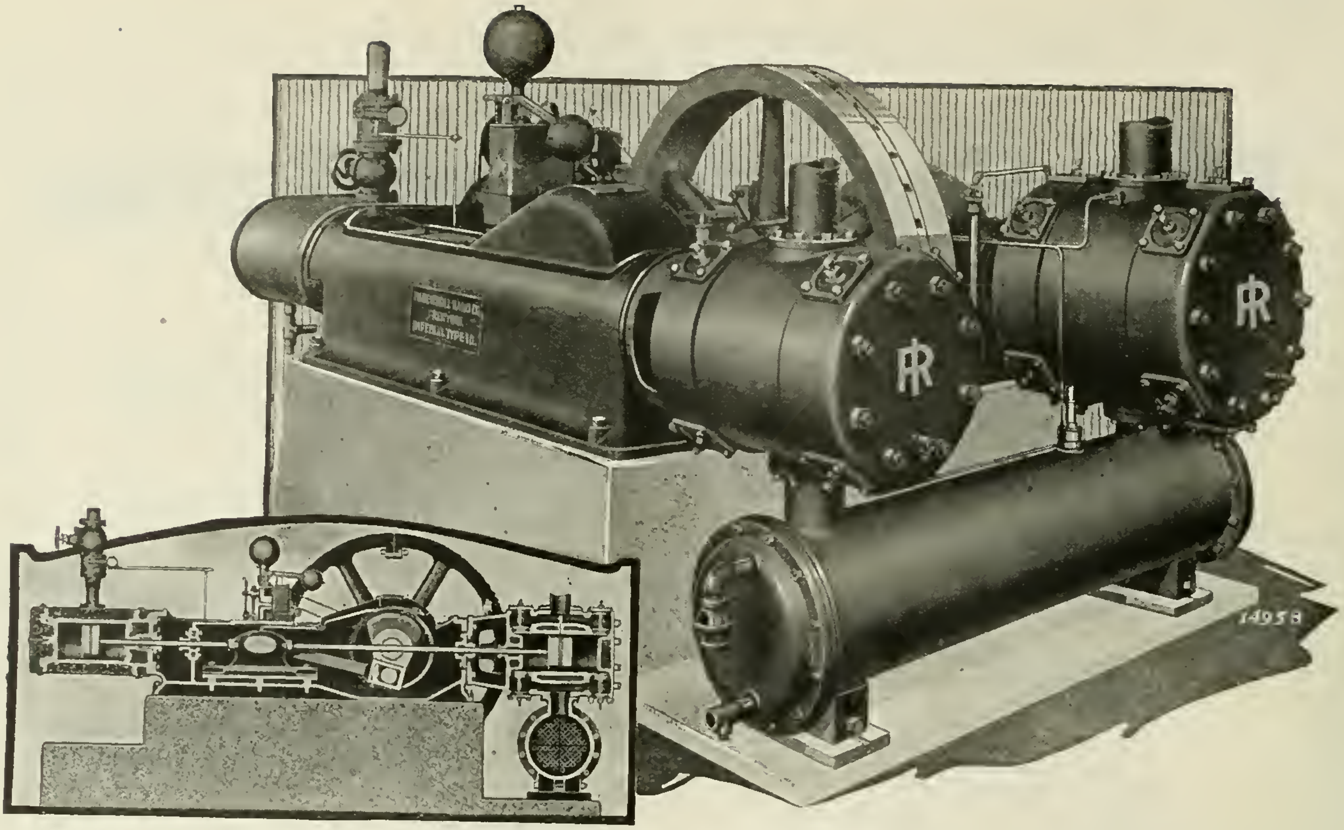
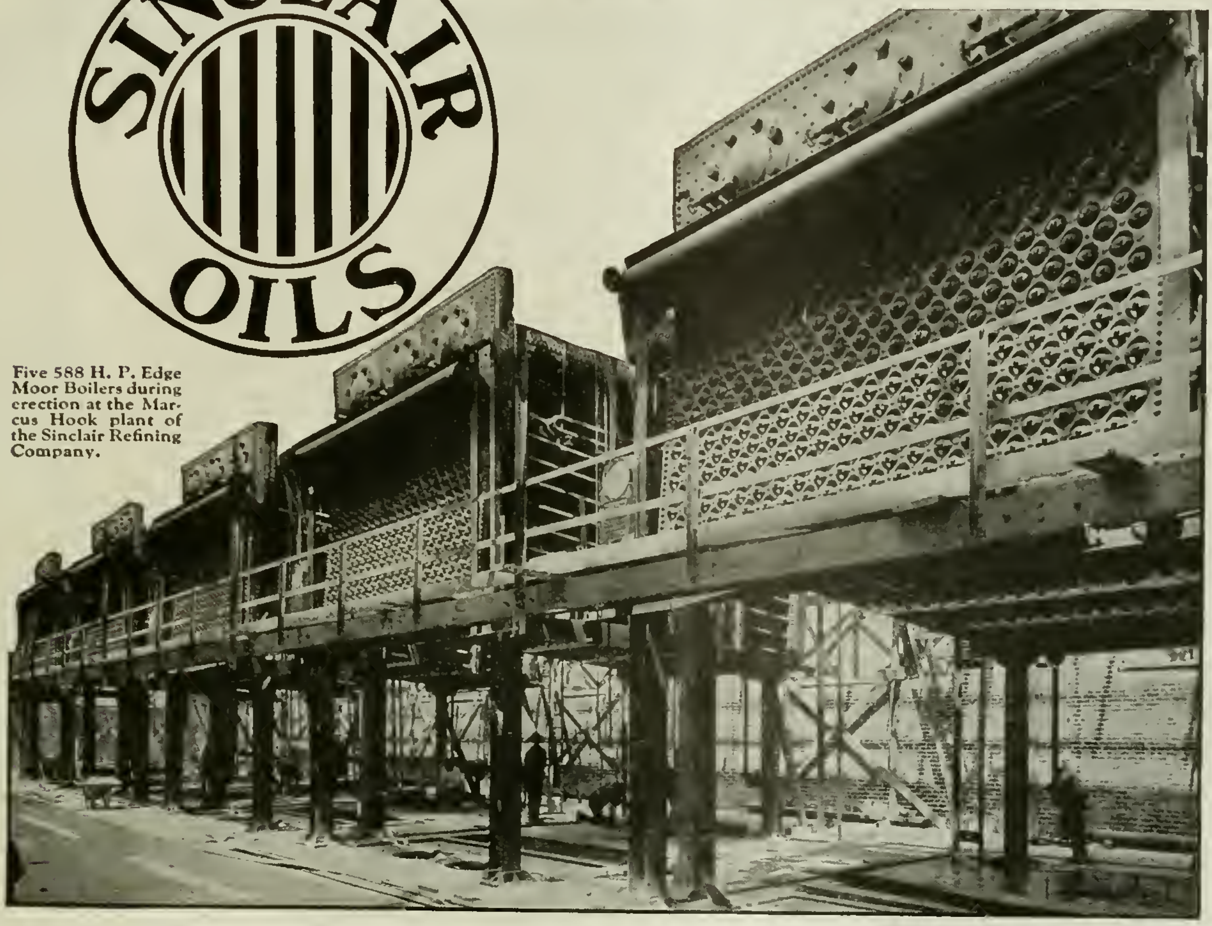
ALLIS-CHALMERS MANUFACTURING COMPANY

MILWAUKEE, WIS., U.S.A.



SINCLAIR OILS



Five 588 H. P. Edge Moor Boilers during erection at the Marcus Hook plant of the Sinclair Refining Company.

THE Sinclair Refining Company, one of the country's greatest producers and refiners of petroleum products, is another of the many industrial leaders that are reducing power costs and increasing boiler room efficiency with Edge Moor Boilers.

Four of the big Sinclair plants are equipped with 18 Edge Moor Boilers totaling more than 10,500 B. H. P. Three years after purchasing the boilers for their plants at Coffeyville and Kansas City, Kansas, repeat orders were placed for five Edge Moor boilers for the Marcus Hook, Pa., plant and four for the Houston, Texas, plant.

Edge Moor Water Tube Boilers are designed and built to meet the requirements of modern power plants. Construction details and performance records are shown in the Edge Moor catalogue. Tell us where to send your copy.

New York
Chicago
St. Paul

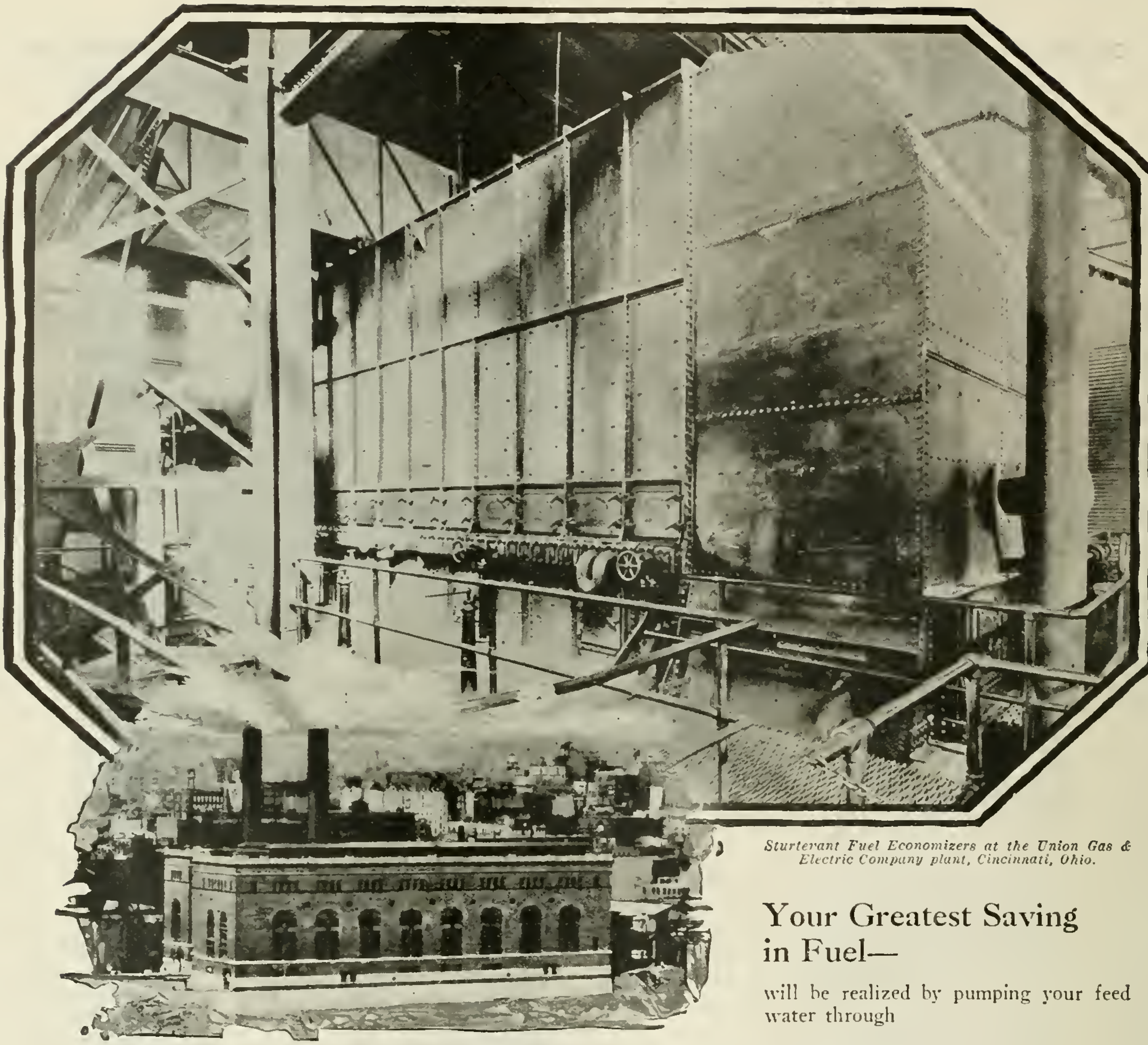
EDGE MOOR IRON COMPANY
Established 1868
EDGE MOOR, DELAWARE

Boston
Pittsburgh
Charlotte

EDGE MOOR Water Tube BOILERS

EDGE MOOR BOILERS EDGE MOOR, DEL. U.S.A.

FOR INCREASED FUEL ECONOMY



Sturtevant Fuel Economizers at the Union Gas & Electric Company plant, Cincinnati, Ohio.

Your Greatest Saving in Fuel—

will be realized by pumping your feed water through

STURTEVANT FUEL ECONOMIZERS

The water is heated to within a few degrees of steam temperature by using the waste heat of the flue gases which surround the tubes. Heat which is ordinarly wasted up the chimney is reclaimed and returned to the boilers.

It is commonly understood that for every 11% rise in feed water temperature there is a saving of 1% in the fuel bill. Sturtevant Economizers raise the temperature from 100 to 150 degrees.

Fixed charges are low, due to the construction. Sturtevant patented tapered metal-to-metal joints eliminate leakage loss and make it easy to replace any tube. Gaskets or cement are not used.

Your installation presents its own peculiar problem. Our engineering department is available for consultation without obligation. Why not learn what Sturtevant Fuel Economizers can save in your plant.

B. F. STURTEVANT COMPANY, HYDE PARK, BOSTON, MASS.

Sales Engineering Offices:
Atlanta, Ga.
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Chicago, Ill.
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PUTS AIR TO WORK

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Springfield, Mass.
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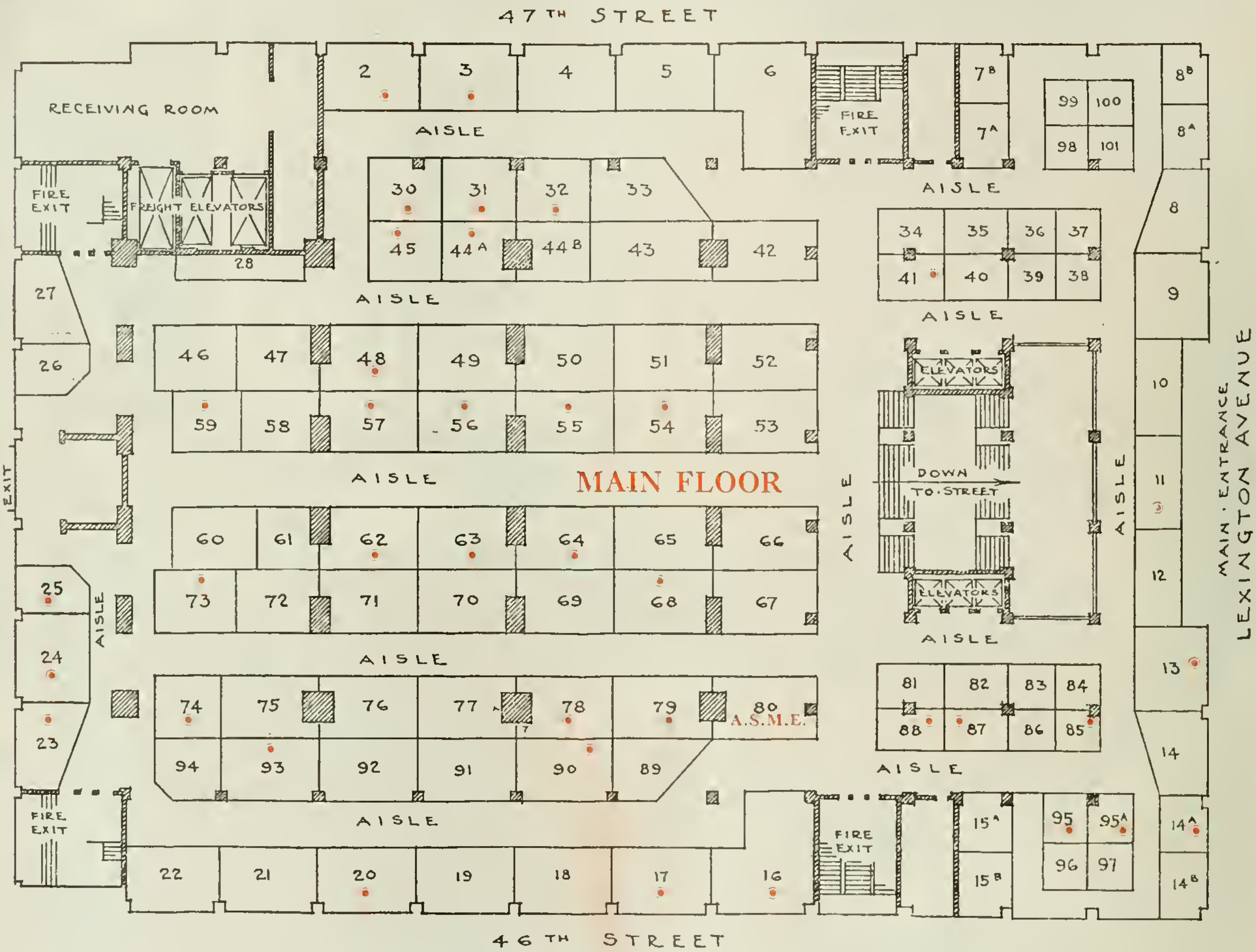
746


POWER
SHOW
SECTION
SECOND
NATIONAL EXPOSITION
of POWER and
MECHANICAL ENGINEERING
December 3rd to 8th
Grand Central Palace
New York, N. Y.
Diagram of Floor Spaces
and List of Exhibitors
Given on the
Two Following Pages.
POWER SHOW
MECHANICAL
ENGINEERING
INCLUDING THE ENGINEERING INDEX

Diagram of Floor Spaces and List of Exhibitors at Second



INFORMATION regarding the exhibits or products of firms listed in bold face type below is given in the following color pages. Each advertiser's booth may be located readily by referring to the numbered diagram of floor spaces shown above, where it is marked by a red dot.

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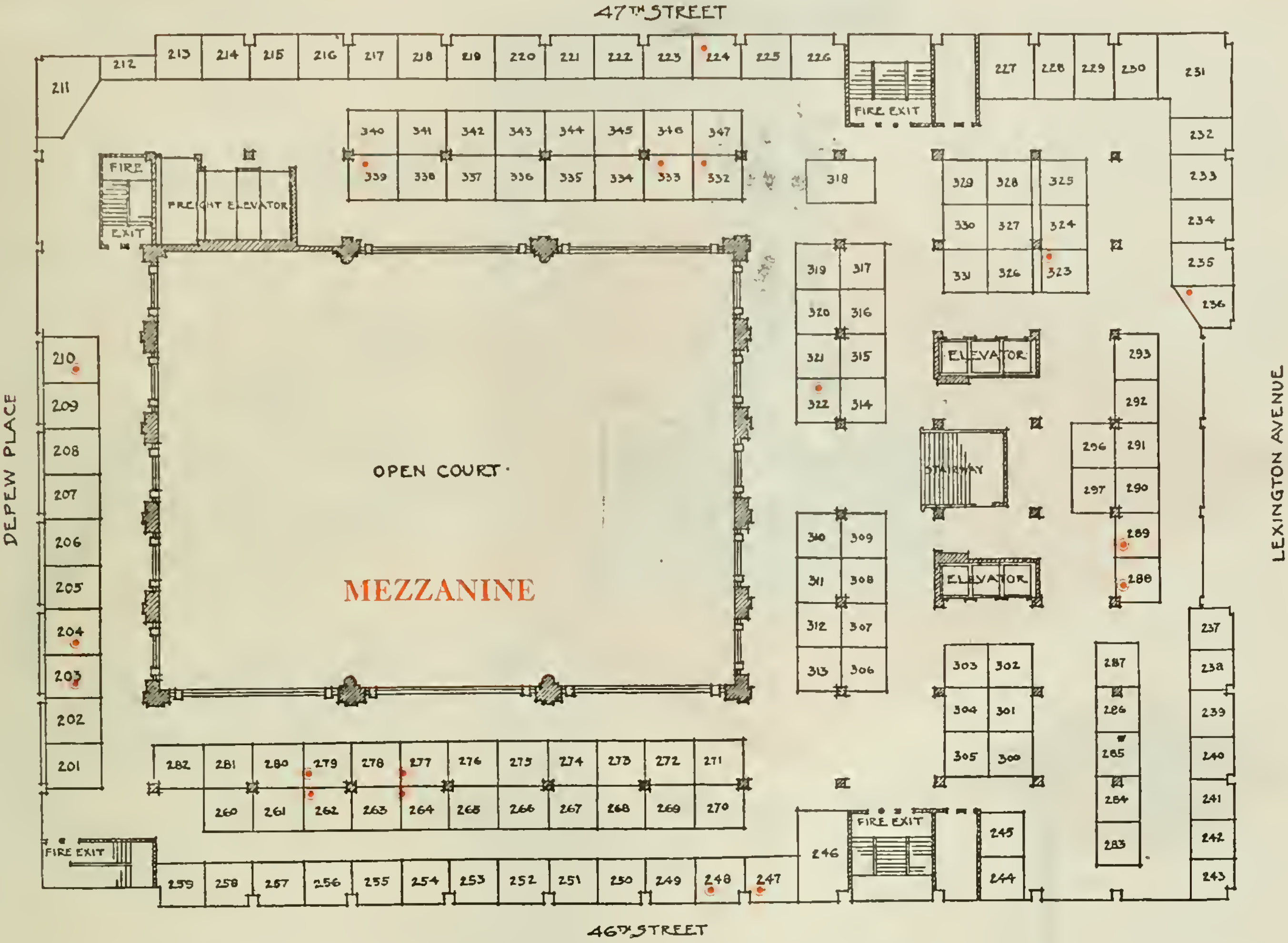
National Exposition of Power and Mechanical Engineering



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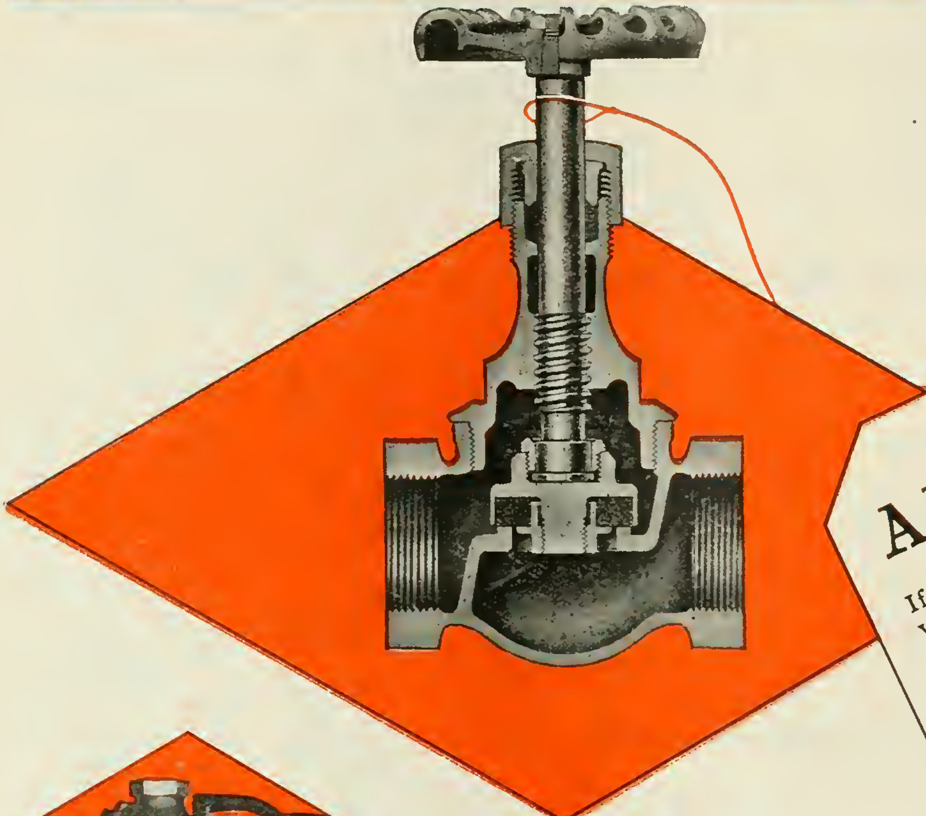
Power Show BOOTH No. 90 Grand Central Palace - New York, N.Y. December 3rd to 8th



A Fair Offer

If you will put a Jenkins Valve on the worst place you can find, where you cannot keep other valves tight, and if it is not perfectly tight, or does not hold steam, oil, acids, water, or other fluids, longer than any other valve, you may *return it and your money will be refunded.*

Fig. 720, Bronze Rapid Action Valve

The Jenkins Diamond
your guide to economical valve service

The man who actually knows valves and valve requirements, judges valve economy by valve service.

To him the most economical valve is the valve that operates satisfactorily and does its job well for the longest time.

And for that reason, he specifies Jenkins Valves wherever a valve is required. Long usefulness, years and years of service, prove the wisdom of his choice.

He specifies Jenkins "Diamond Marked" Valves, for he knows that Jenkins service can be expected only from genuine Jenkins Valves.

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Visit us at Space 90 Power Show

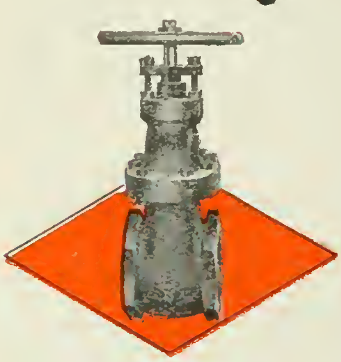


Fig. 325, Screwed, Standard Iron Body Gate Valve

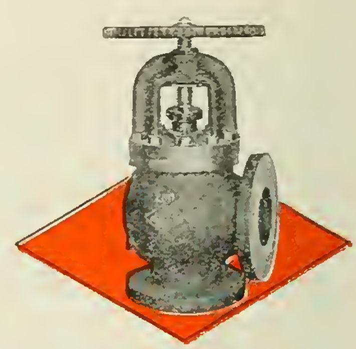


Fig. 293, flanged, Extra Heavy Iron Body Automatic Equalizing Stop and Check Valve

Fig. 709, Bronze Air Gun

JENKINS BROS.

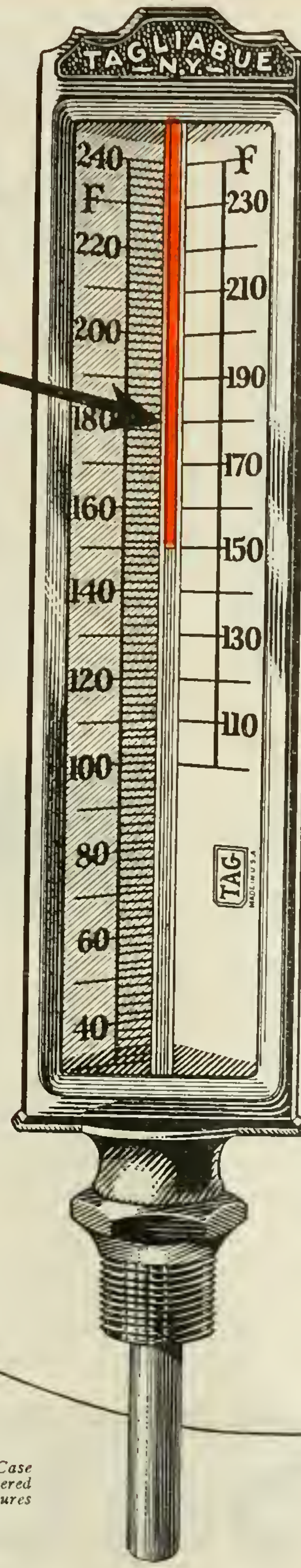
80 White Street .... New York, N. Y.
524 Atlantic Avenue .... Boston, Mass.
133 No. Seventh Street .... Philadelphia, Pa.
646 Washington Boulevard .... Chicago, Ill.

Jenkins Valves

SINCE 1864

Power Show | BOOTH No. 59 | Grand Central Palace – New York, N.Y. December 3rd to 8th

The TAG-HESPE RED READING COLUMN *for* MERCURY THERMOMETERS



Specifications—Bronze Case with Glass Front; Silvered Scale with Black Figures and Graduations.

EASY TO READ—The TAG-Hespe Column, an EXCLUSIVE TAG Feature, shows as a broad red line from the top of the mercury column to the top of the tube. When the mercury rises it covers more of this red line; when the mercury falls a correspondingly greater length of the red line is exposed. The decided contrast between this bright red line and the metallic grey of the mercury brings to the accurate mercury thermometer the easy readability of the red spirit instrument.

TAG-Hespe thermometer glass (tubing) is in every way similar to ordinary lens front thermometer glass except that in TAG-Hespe glass the BACK of the fine capillary bore (up and down which the mercury travels) is made of bright red GLASS. This red streak of glass extends all the way from the top of the thermometer down to the bulb. Note particularly that the red glass is in the back of the bore and NOT at the back of the tube.

The red line attracts the eye at first glance and it is easy to follow it down and take the reading at its bottom which is, of course, the top of the mercury column. The broad line of red stands out like a semaphore set at danger. You CAN'T miss it.

HONEST AND STURDY RECORDING AND DIAL-INDICATING THERMOMETERS give you accurate and reliable information of your various apparatus and processes.

SAFETY IN OIL BURNING—The TAG Shut-off Valve is connected in the fuel lines of oil burner equipped boilers and other devices and automatically shuts off the oil flow, the instant that the steam or oil pressure used for atomizing, falls below the required minimum. The TAG Valve LOCKS ITSELF and cannot be reopened (even though the atomizing pressure is brought up to the required point) until the trip lock mechanism is reset by hand. Absolutely prevents oil leakage into furnace and the possibility of a disastrous explosion.

CO_2 AND CO RECORDS on the same chart enable you to operate just at the critical point, on one side of which is the unnecessary air excess loss and on the other side, the combustible gas loss due to not enough air. The highest possible CO_2 without CO can be secured at all times through the dependable guidance of the TAG-Mono Duplex. The continuous record of BOTH CO_2 and CO tells you at a glance whether your stoker and draft adjustments are right and also aids you in discovering faulty furnace conditions.

TAG LIABUE MFG. CO. N.Y.

Since 1769

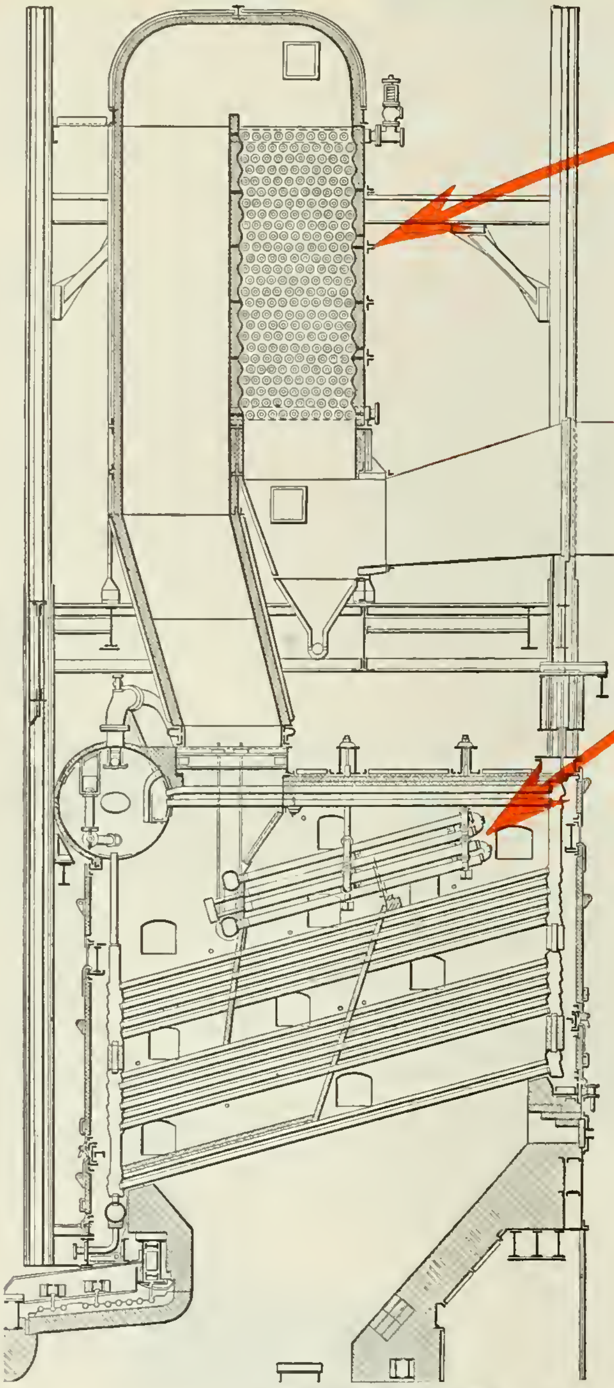
SEND FOR CATALOG M-640

C. J. TAGLIABUE MFG. CO. 18 to 88 Thirty-Third St., BROOKLYN, N. Y.

AUTOMATIC CONTROLLERS FOR TEMPERATURE, PRESSURE, HUMIDITY, TIME, LEVEL, AND CONDENSATION; INDICATING AND RECORDING THERMOMETERS; HYDROMETERS; OIL TESTING INSTRUMENTS; TAG-MONO GAS ANALYSIS RECORDERS, ETC.

BOSTON PITTSBURGH CHICAGO TULSA SAN FRANCISCO TORONTO

Power Show BOOTH No. 20 Grand Central Palace – New York, N.Y. December 3rd to 8th

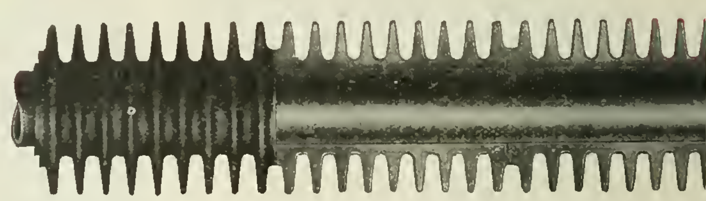


For better

preheat your boiler feed

It is an established fact that the fuel consumption under a boiler is reduced by approximately one per cent for each ten degrees added to the feed water if the heat to do this work is reclaimed from the waste gases. A Foster Economizer that adds 100 degrees to the boiler feed effects a 10% fuel saving.

The Foster Economizer can be installed in the boiler flue with unimportant alterations and because of the patented Foster construction occupies only about one-half the space required by other preheating surfaces.



The FOSTER Patented

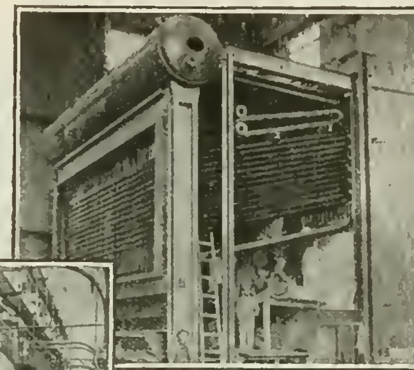
The records of more than 10,000 installations in stationary power plants, extending over 20 years of service and in all conceivable operating conditions, have firmly established the practical advantages of the special Foster construction for superheaters and economizers.

In the Foster construction, the seamless inner steel tube and the outer ribbed cast iron rings into which the tube is tightly fitted, form a combination that ideally meets the two superheater requirements of strength and resistance to corrosion.

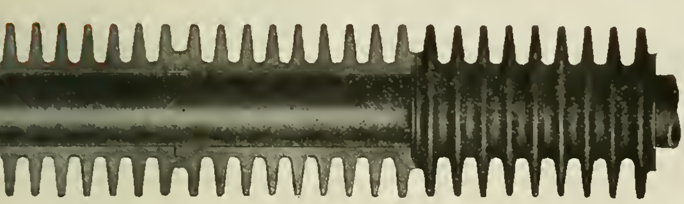
FOSTER ECONOMIZERS

plant economy

superheat your steam



Superheating has long been known to be one of the most economical means of improving power plant economy. In the boiler, superheating abstracts additional heat from the furnace gases; in the pipe lines, it reduces condensation losses; and in engines and turbines it enables a given weight of steam to do more work. The low initial cost, negligible upkeep, thorough reliability and marked improvement in boiler and engine economy of the thousands of Foster installations have caused the Foster Superheater to be generally regarded as standard equipment for the up-to-date and efficient plant.



The Foster Radiant Heat-Absorbing Superheater

has great advantages for high superheat conditions when used either alone or in combination with the Foster extended surface connection type superheater. Write for full information.

Extended Surface

Furthermore, the heavy ribbed cast iron rings, by presenting to the furnace gases from four to six times as much superheating surface as the bare tube construction, increase the superheating effectiveness, and steady the superheat during periods of fluctuating steam demand.

It will pay you to investigate further the advantages of Foster Superheaters and Economizers. Write for bulletins and tell us your operating conditions so we can give you definite figures—without obligation—of the savings possibilities in your plant.

Some 1923 Foster Installations

	B. hp.
Lehigh Portland Cement Co. Mason City, Ia.	5000
American Woolen Co., Lawrence, Mass.	4020
Texas Company, Port Arthur, Tex.	5952
Sinclair Refining Co., Houston, Tex.	2352
American Hardware Corp., New Britain, Conn.	2024
Texas Sugar Refining Co., Galveston, Tex.	3095
Bigelow Hartford Carpet Corp., Tompsonville, Conn.	2760
Northern States Power Co., St. Paul, Minn.	15000
Moline Rock Island Mfg. Co., Moline, Ill.	4178
Public Service Corp. of Colorado, Boulder, Col.	5600
Milwaukee Elec. Ry. & Lt. Co., Milwaukee, Wis.	14120
Metropolitan Edison Co., Reading, Pa.	7470
Appalachian Power Co., Glen Lyn, Va.	4928
United Elec. Lt. & Power Co., New York, N. Y.	4650
Cleveland Electric Ill. Co., Cleveland, O.	12000

POWER SPECIALTY CO.

111 Broadway, New York

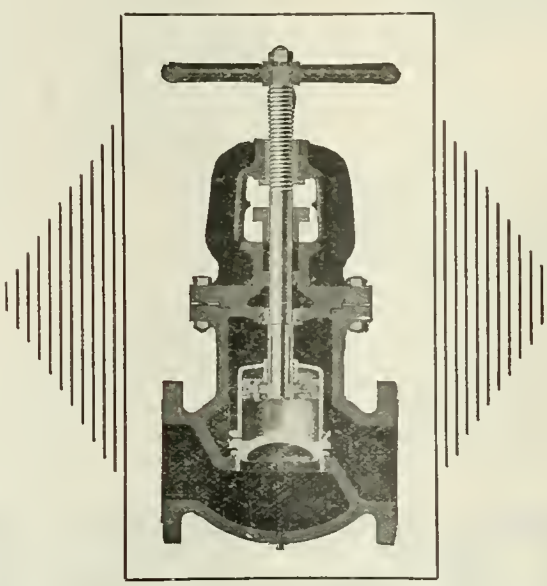
Boston Chicago Philadelphia San Francisco Pittsburgh Kansas City Dallas London, Eng.

FOSTER SUPERHEATERS

Power Show BOOTH NO. 32 Grand Central Palace ~ New York, N.Y. December 3rd to 8th

EDWARD Valves

Have been pioneers in serving the needs of the country's foremost engineers in their steady march toward higher efficiency of power plants. In this day of ever higher temperatures and pressures EDWARD Valves are not only keeping pace with the demand—they are anticipating it.

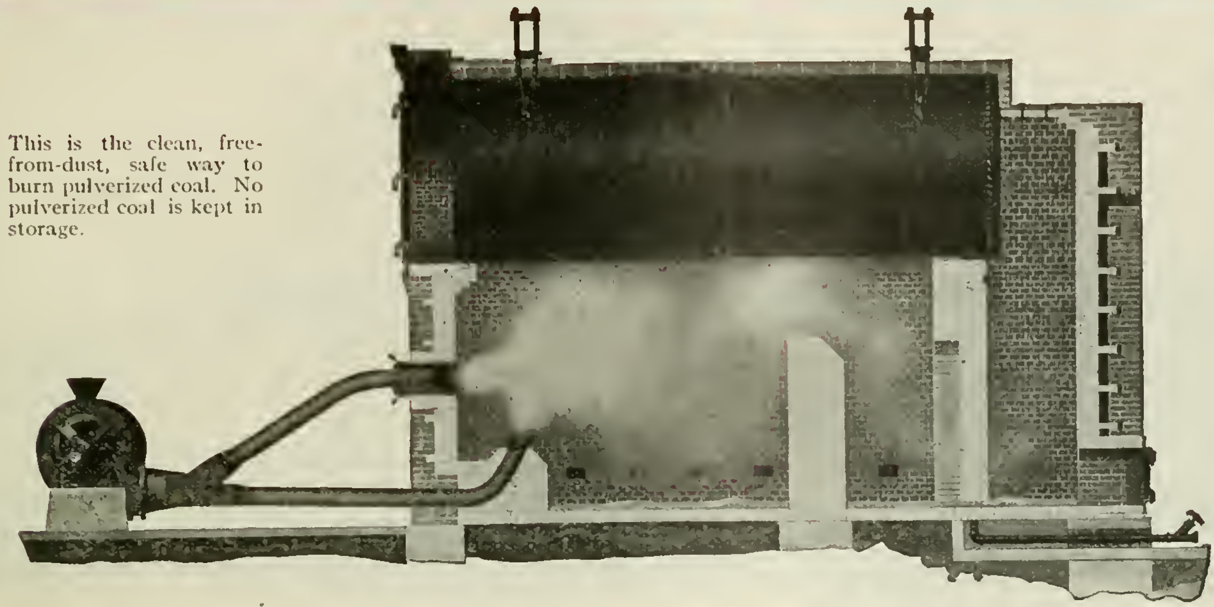


The Edward Valve & Manufacturing Co.

Main Office and Works: East Chicago, Indiana.

AGENTS IN ALL PRINCIPAL CITIES

Power Show BOOTH Nos. 288 & 289 Grand Central Palace - New York, N.Y. December 3rd to 8th



This is the clean, free-from-dust, safe way to burn pulverized coal. No pulverized coal is kept in storage.

Coal Consumption Cut 30%—Labor Requirements One-Third

And, on top of that, production increased from 20 to 25 per cent!

That's the record Erie City Pulverizers "put over" in a certain plant.

The first installation consisted of two Erie City Pulverizers, 3,000 lbs. capacity each.

Recently we received a repeat order for eight more pulverizers of the same capacity.

Tests that have been made demonstrate conclusively that you can get more steam per pound of coal from pulverized coal than from any other method of burning coal. A repeat order like this proves that Erie City Pulverizers are giving entire satisfaction to pulverized coal users.

Ask for copies of these "Test Reports."

PULVERIZED
Coal Equipment

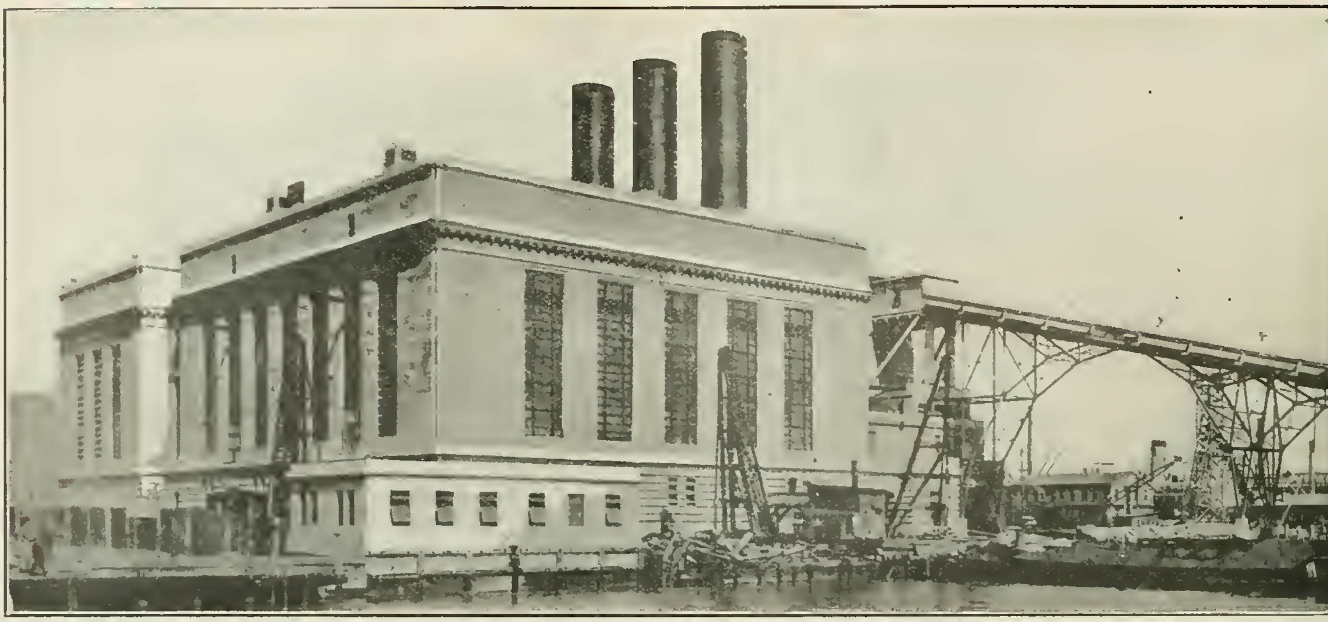
Erie City Iron Works

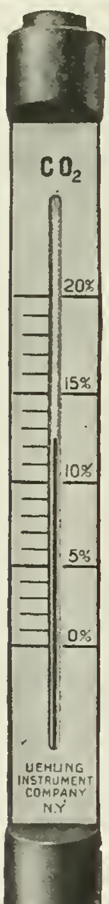
Erie, Pa., U. S. A.

Manufacturers, also, of Erie City Vertical Water Tube Boilers, Erie City Horizontal Water Tube Boilers, "Economic" Boilers and Lentz Poppet Valve Engines, as illustrated and described on pages 56 and 57 of the 1923-24 A.S.M.E. Condensed Catalogues.

Look us up at the Power Show—Booth Nos. 288 & 289

Power Show BOOTH No. 45 Grand Central Palace – New York, N.Y. December 3rd to 8th





Auxiliary CO_2 Indicator for mounting at the boiler front.

6 More for Delaware

Just installed six more UEHLING CO_2 RECORDERS at the Delaware Station of the Philadelphia Electric Company—making a total of FOURTEEN that are in regular service guiding combustion economy at this modern central station.

In addition to the above, nine more UEHLING CO_2 RECORDERS have been at work for several years in the other plants of this company.

The simplicity of the UEHLING appeals to the practical man. The indicators on the boiler fronts are as easy to read as a big thermometer and give the firemen continuous visual evidence of the condition of the fires. The continuous accurate records of CO_2 drawn in the chief engineer's office are an invaluable aid in supervision and are proof of the combustion efficiency maintained by the men at all times.

"Pyro-porus" filtration protects the sampling line and instrument against fouling and corrosion. No liquid chemicals are employed. Absorption is accomplished by a dry carton that lasts a long time and which can be renewed in a few minutes at trifling cost.

Our engineers will be glad to show you how UEHLING INSTRUMENTS will save fuel for you. Write for Bulletins 220 and 221, which contain instructive tables and charts.

SEE THE NEW UEHLING CARBON MONOXIDE (CO) RECORDER AT OUR BOOTH NO. 45 AT THE POWER SHOW. This instrument completes the story of combustion and is used in conjunction with UEHLING or other CO_2 RECORDERS

UEHLING INSTRUMENT CO.

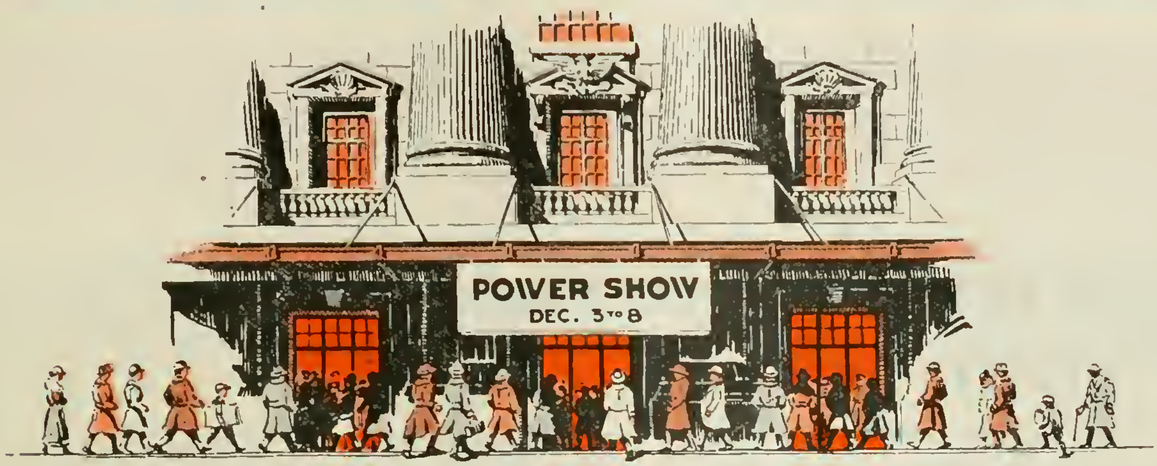
28 Vesper St. Paterson, N. J.

Canadian Representatives—Combustion Engrg. Corpn., Ltd., Toronto, Ont.
Mexican Representatives—Mine & Smelter Supply Co., El Paso, Texas

Uehling Continuous CO_2 Recorder for placing in the chief engineer's office at any distance.

CO_2 Uehling Recorders

Power Show BOOTH No. 73 Grand Central Palace - New York, N.Y. December 3rd to 8th



Straight Ahead — and turn to the right!

During the week of December 3rd, if you can possibly make it, drop everything and spend a profitable and interesting afternoon or evening at the Exposition of Power and Mechanical Engineering at The Grand Central Palace, New York City.

In this great building you will see spread before you the most magnificent display of mechanical equipment and supplies ever brought together under one roof.

Once inside, go straight ahead down the nearest aisle to the very end and *turn to the right*. This will bring you to Space 73 —the Tide Water booth.

Here you will see an exhibit of unusual interest—daylight motion pictures showing Tide Water's latest film, "America's Industries"—a model oil derrick, an exact replica of the kind used in the Southwestern oil fields and an elaborate display of oil and grease samples including the famous Tide Water Power Group.

One good turn deserves another. Come right inside our booth. You will at all times find a crowd of Tide Water men on hand to greet you. We want you to know all about Tide Water and what is behind it—our oil fields, our refinery, our products, our sales organization. . . . .
One of our representatives will be glad to tell you the whole story.

And if you have any perplexing lubricating problems, he will gladly lay before you scientific recommendations for the more economical operations of your machinery—recommendations based on Tide Water's 45 years' experience in the manufacture of lubricants of the highest known quality.

Furthermore, if you need anything, any time, in the lubricating line, just write 11 BROADWAY or call WHITEHALL 6000.

It's the *right turn* for you.

TIDE WATER

TIDE WATER OIL SALES CORPORATION
ELEVEN BROADWAY NEW YORK

45 BOILERS IN 11 FORD PLANTS
EQUIPPED WITH ELESCO SUPERHEATERS

Mr. Ford is as particular about efficiency in his boiler room as in his machine shops. The most remarkable production methods in existence are matched by boiler room efficiency.

Succeeding contracts for Elesco Superheaters at various Ford plants, irrespective of make, type and size of boilers, are placed on the basis of the performance of the preceding installation.

These Plants are as follows:

Power Station No. 1	River Rouge Plant, Detroit, Mich.
	8—2647 hp. Ladd Vertical Boilers.
Power Station No. 3	River Rouge Plant, Detroit, Mich.
	8—400 hp. Wickes Vertical Boilers.
Highland Park Plant, Detroit, Mich.	1—733 hp. Badenhausen Boiler.
	1—746 hp. McAleenan Boiler.
Cement Plant, Highland Park Plant, Detroit, Mich.	
	1—800 hp. Ladd Vertical Boiler.
Lincoln Place, Detroit, Mich.	2—500 hp. B. & W. Stirling Boilers.
Iron Mountain, Mich.	4—309 hp. Wickes Vertical Boilers.
	4—400 hp. " " "
	3—1361 hp. McAleenan Boilers.
Burnham, Ill.	4—500 hp. Connelly Boilers.
Walkerville, Ont.	3—1361 hp. McAleenan Boilers.
Kearney, N. J.	4—500 hp. B. & W. Stirling Boilers.
Buffalo, N. Y.	1—208 hp. Badenhausen Boiler.
Kansas City, Mo.	1—400 hp. Badenhausen Boiler.

Write for F-T Series Bulletins

ELESCO

17 E. 42nd St., New York

Canada:—The Superheater Co., Ltd., Montreal

Power Show BOOTH No. 62 Grand Central Palace - New York, N.Y. December 3rd to 8th

A corroded Condenser Tube
Mag. 75×. Etch $NH_4OH + H_2O_2$

CORROSION

AS REVEALED BY THE MICROSCOPE

AN OPPORTUNITY will be given to visitors of the Power Show to examine actual specimens of corroded tubing under a microscope.

The causes of condenser tube failures—and the steps taken to retard corrosion will be demonstrated. Engineers should take this opportunity to learn the latest developments in regard to condenser tubing.

Visit our Booth No. 62

National Exposition of Power and Mechanical Engineering—Grand Central Palace, New York

December 3 to 8, 1923

Buy Condenser Tubes on an Engineering Basis

SCOVILL CUP DRAWN Admiralty Condenser Tubing is made to the following specifications:

1. Electric Furnace Brass Composition—Copper 70% min., Tin 1% min., Zinc remainder.
2. Cupped from wrought sheet the surface of which had been milled.
3. Finished Tubes will stand an expansion of 25% min.
4. Microstructure uniformly recrystallized—.025mm. max.
5. Guaranteed against season cracking or splitting.

Meets all Navy and A.S.T.M. Specifications.

Write for Revised Edition of "Tube Facts"

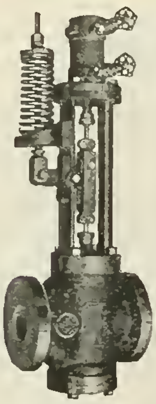
BRASS MILL PRODUCTS—MFG. GOODS TO ORDER

Main Office, Mills and Factories—Waterbury, Conn.
Sales Offices:—280 Broadway, New York
10 High St., Boston 224 W. Lake St., Chicago
1213 W. 3rd St., Cleveland Penna. Bldg., Philadelphia
Rialto Bldg., San Francisco

ESTABLISHED 1802
SCOVILL
MANUFACTURING COMPANY

Scovill Cup Drawn Admiralty Condenser Tubing
Mag. 75×. Etch $NH_4OH + H_2O_2$

Power Show BOOTH No. 59 Grand Central Palace ~ New York, N.Y. December 3rd to 8th



Mason Boiler Feed Line Regulator

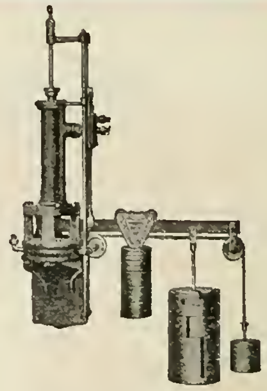
For controlling steam-driven boiler feed pumps. Size ½ in.-1½ in. bronze body. Size 2 in.-4 in. iron body, bronze mounted.

Mason Standard Reducing Valves

Reduces and maintains even pressure of steam and air regardless of the variation of the initial pressure or of the volume of steam and air required. Sizes ½ in.-2 in. bronze body. Sizes 2 ½ in.-10 in. iron body, bronze mounted.

Mason Pump Regulator

For controlling the discharge pressure of steam-driven pumps—10 to 150 lb. pressure. Sizes ½ in.-1½ in. bronze body. Size 2 in.-4 in., iron body, bronze mounted.



Mason Hydraulic Damper Regulator

Assures accurate regulations of boiler pressure—Double Acting—positive movement and actuated by water pressure in both directions. Equipped with 2¼ in., 3 in., 4 in. and 5 in. diameter operating cylinder.

Better Control

of Operating Pressures Reduces Boiler Room Costs

There can be no dispute about this. It is virtually an axiomatic truth. The only question is, how are you going to get it?

For forty years the Mason Regulator Company has specialized in the development and manufacture of dependable automatic Pressure Regulating Devices for the control of steam, air and water, in all lines of service—heating, power and process work.

MASON Regulators are conspicuous for accuracy, low maintenance and absolute dependability. Buy them through your dealer. Write us for Catalog.

TRADE MARK MASON

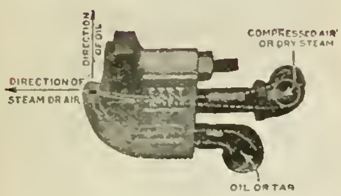
MASON REGULATOR CO.

Adams & Medway Sts., Boston, Mass.

Power Show BOOTH No. 14A Grand Central Palace - New York, N.Y. December 3rd to 8th

Liquid Fuel Means—

temperature control within 10°
increased steam capacity
no fuel or ash handling



"CALOREX" Burner

External atomizing—no tubes or needle points to clog or carbonize.

Burns fuel oil, crude oil, or tar.

Can be designed to throw a long, narrow flame or a fan-shaped flame up to 7 feet in width.

Simple to operate—only one control valve.

Economical.

Successfully Used in—

High-Pressure Boilers
Low-Pressure Boilers
Heat-Treating
Brazing
Melting
Forging
Welding
Smelting
Pipe-Bending
Tempering
Glass
Rolling Mill Work
Cement Kilns
Potteries
Locomotives

THE use of liquid fuel also means that fires can be instantly lighted and furnaces or boilers brought to working temperature; temperature can be controlled within 10°. Liquid fuel occupies but one-third space of its equivalent in coal. You will get the maximum efficiency from liquid fuel by using

W. N. Best "CALOREX" Burners
and Oil-Burning Equipment

W. N. Best equipment is the product of 34 years of experience in liquid fuel combustion. Each type is designed for a specific use—boiler work, heat-treating, welding, etc. Careful design, rigid testing, and correct installation of W. N. Best equipment are enabling 12,000 manufacturers to reduce fuel costs and to increase production.

48,000 Burners in Use

Throughout the United States and in many foreign countries, in every line of business, 48,000 W. N. Best CALOREX Burners are giving efficient, economical service. They can be applied in your own plant with equal success. In fairness to yourself give us the details of your business—type of work, plant, horsepower, etc.—and without obligation let us show you exactly what saving you will effect.

If you want to reduce costs—write today

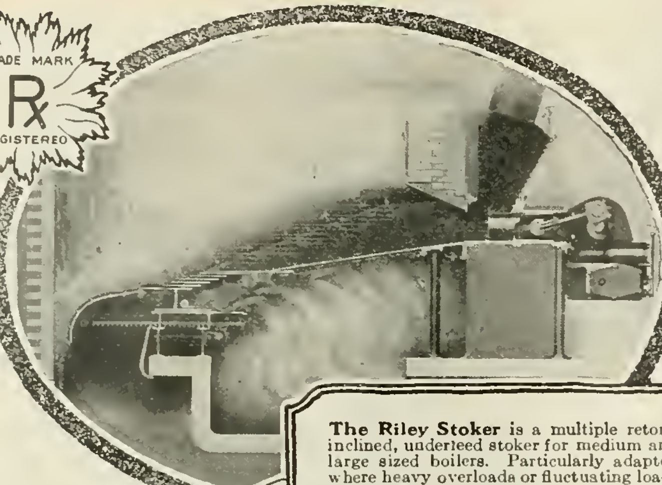
W. N. BEST Corporation
Engineers in Caloric
11 Broadway New York, N. Y.

Visit our Demonstration—Booth 14A, 1st Floor

(See Our Data in 1923-24 A.S.M.E. Condensed Catalogues of Mechanical Equipment)

Power Show | BOOTH No. 79 | Grand Central Palace ~ New York, N.Y. December 3rd to 8th

TRADE MARK Rx REGISTERED



The Riley Stoker is a multiple retort, inclined, underfeed stoker for medium and large sized boilers. Particularly adapted where heavy overloads or fluctuating loads are carried. Exclusive features include: Reciprocating Retort Sides, Moving High Side Wall Tuyeres, 2-speed Gear Box, Rocker Dump, Safety Shearing Pin.

A Type for Every STOKER Need

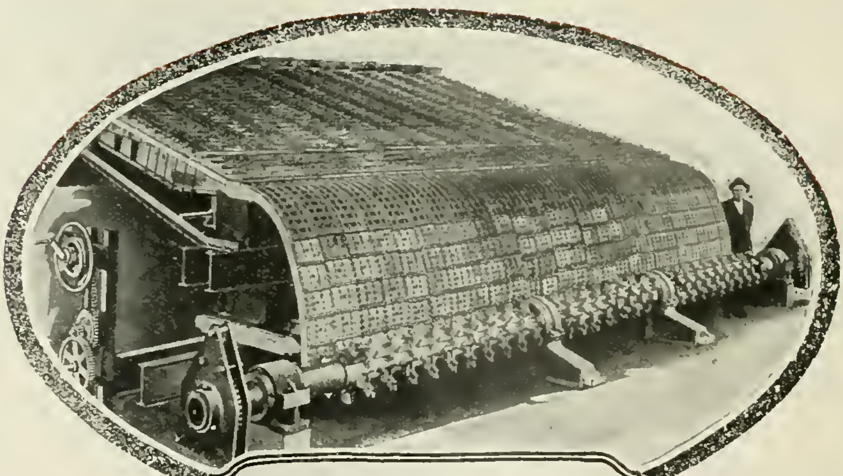
Whether you use big boiler or small boiler, good coal or poor coal, forced draft or natural draft,

We have a type that you will like

SMA STOKER MANUFACTURERS ASSOCIATION

Dealing in Facts—Because the future of automatic stoking rests upon the ethical standards of the men and firms behind the industry—because its present standing can be preserved only by eliminating of exaggerated claims—the Stoker Manufacturers Association, of which this organization is a part, has made the honest dealing in facts one of the qualifications for membership.

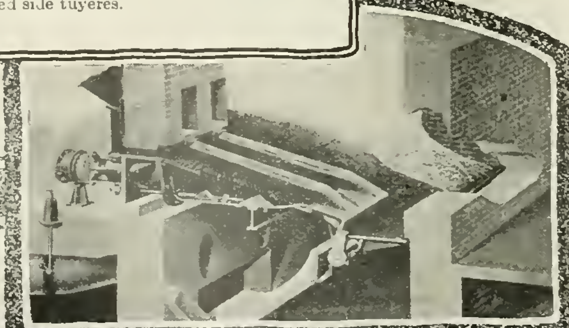
BURN COAL "The *basic* fuel"

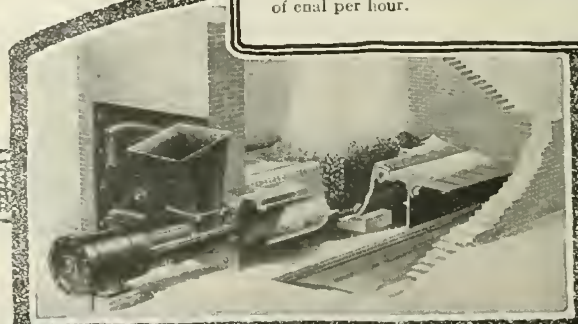


The Riley "Super-Stoker" is made for the large central stations and industrial plants where high capacity and maximum efficiency are desired. Built in depths up to 20′ and having a coal burning capacity per retort up to 3000 pounds of coal per retort per hour, it is applicable to boilers of large size.

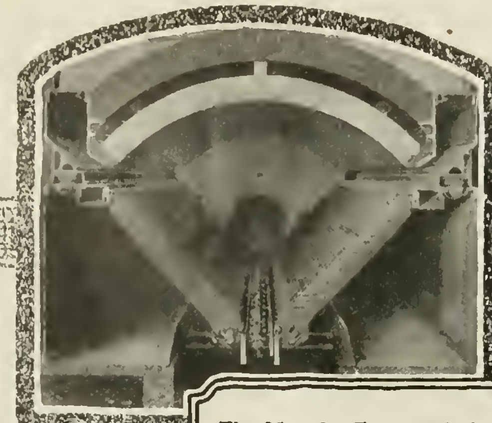
The Jones "A-C" is a steam-driven, multiple retort, underfeed stoker for use with boilers from 300 H. P. up. Characteristic features include a large retort volume, complete absence of avalanching, individual control of retorts and high, air-cooled side tuyeres.

The Jones "Standard" Side Dump Stoker has the basic Jones features and in addition, a side dump, forming a self-cleaning mechanism. Only slight excavation is required; the cost is low. This stoker gives high efficiency and has a fuel burning capacity of 1,200 to 1,800 pounds of coal per hour.





The "Lateral Retort" Stoker is an all underfeed multiple retort, side cleaning stoker requiring no basement. This brings to smaller boiler units (from 150 H. P. to 500 H. P.) the proved advantages of underfeed, multiple retort, stoker firing.



The Murphy Furnace is designed for any type of boiler from 50 H. P. up to the larger sizes for which the multiple retort underfeed stoker is best suited. It is a natural draft furnace and requires no fan or blower equipment. Particularly suited for small or medium size boilers carrying a steady load.

TRADE MARK

At Booth No. 79

You are cordially invited to visit Booth No. 79 and see our display which will be of particular interest to power plant managers and engineers interested in efficient combustion.

See the "Lateral Report" Stoker—the all-underfeed, side cleaning stoker which has won such wide acceptance during the past year—set up and in working order.

See the motion pictures showing the actual operation of underfeed stokers. From coal bunker to ash hopper you actually see just what happens including pictures of the fire. Boiler room operation is brought to the exposition floor.

Our representatives will be glad to give you full information and literature covering the service we are prepared to render in the combustion field.

SANFORD RILEY STOKER COMPANY

SANFORD RILEY STOKER CO.

"RILEY" Underfeed Stokers — "JONES" Underfeed Stokers — "MURPHY" Automatic Furnaces

GROUND COAL ENGINEERING CORP. Pulverized Coal Installations

9 Neponset Street, WORCESTER, MASS., U. S. A.

BOSTON, NEW YORK, PHILADELPHIA, PITTSBURGH, BUFFALO, CLEVELAND, DETROIT, CINCINNATI, CHICAGO, ST. PAUL, KANSAS CITY, DENVER, CHARLOTTE, DALLAS

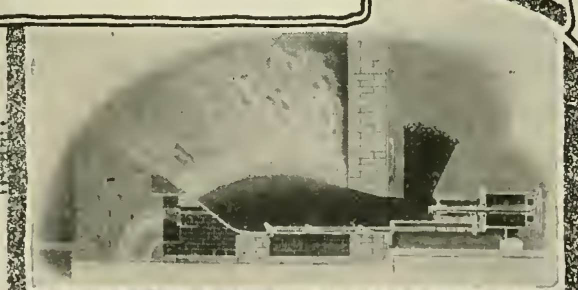
The UNDERFEED STOKER COMPANY OF CANADA, LTD., TORONTO

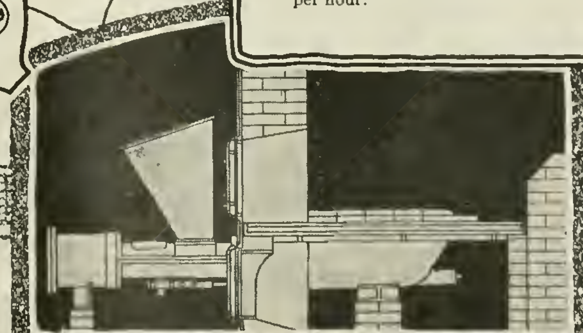
(See Our Data in 1923-24 A.S.M.E. Condensed Catalogues of Mechanical Equipment)

The Jones "Standard" Stoker is applied to boilers from 50 H. P. to 150 H. P. It is moderate in first cost, and since it requires practically no excavation for installation, can be economically installed in existing plants. This stoker has a fuel burning capacity of 800 to 1,200 pounds of coal per hour.

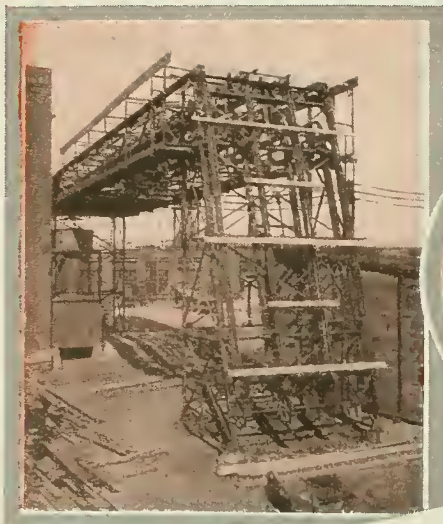
The Jones "Industrial" Furnace Stoker is used in industrial heating operations, metallurgical and chemical furnaces. Fuel burning capacity is 60 to 800 pounds of coal per hour.

JONES STOKER





Power Show BOOTH No. 323 Grand Central Palace ~ New York, N.Y. December 3rd to 8th


G-W Lumber Conveyor

G-W Flight Conveyor

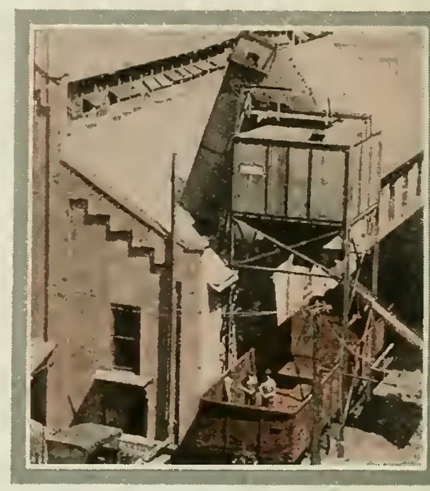

G-W Platform Conveyor

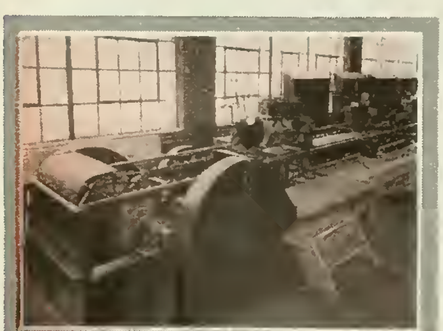
Available Now! Plenty of Help


G-W Coal Elevators and Conveyor

—permanent, economical, and highly efficient mechanical handling "labor." Adaptable to a wide variety of duties, indoors and out.

It is available in many forms, only a few of which are here illustrated. It meets hundreds of elevating and conveying requirements — many of which probably exactly parallel yours.


G-W Ash Elevator


G-W Chain Conveyor

Complete information regarding this G-W Equipment will gladly be supplied at Booth No. 323 Power Show, or by our nearest office below.

Main Office: 18 Hill St., Hudson, N. Y.
District Offices:
New York, 50 Church St. Boston, 24 Milk St.
Chicago, 565 W. Washington St
Pittsburgh, Peoples Bank Bldg.

Plants: Hudson, N. Y. and Oakmont, Pa.


G-W Belt Conveyor

Gifford-Wood Co.

BUILT STRONGER LASTS LONGER

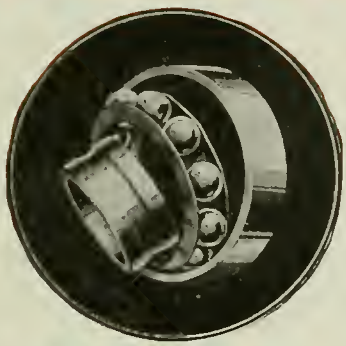
MATERIAL HANDLING EQUIPMENT

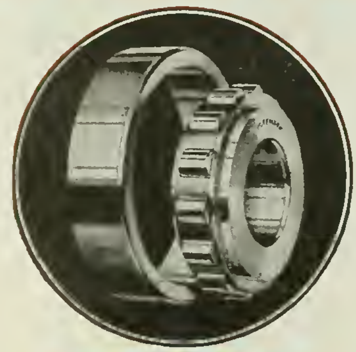
Power Show BOOTH No. 224 Grand Central Palace ~ New York, N.Y. December 3rd to 8th

How Precision Affects Production

To maintain maximum plant output, each productive unit must be kept at top speed, all the time. Only the best machines, with maximum wear resistance, can stand this speed service. Precision—everywhere desirable in a high-duty machine—is fundamentally requisite in the bearings, where the heaviest friction load must usually be carried. For inaccuracies of small moment at moderate speeds, manifest themselves at high speeds in destructive vibration, with excessive friction and wear.

PRECISION BEARINGS





"NORMA"

BALL BEARINGS

Experience has proved that these high-precision units are preeminently adapted to conditions where maximum serviceability and freedom from vibration are sought, under high-speed operation. They have all the load-carrying capacity of any ball bearing, with a speed-ability which no other ball bearing possesses. They have long been the standard bearings in all high-grade automotive magnetos and lighting generators. And other notably successful applications are high-speed grinders and drills, fractional h.p. motors, and electrical utilities.

HOFFMANN

ROLLER BEARINGS

These high-precision, heavy-duty units are designed for conditions involving heavy loads, shocks, jars and vibrations. They have all the speed-ability of the best ball bearings, with a much greater steady load-carrying capacity and with a temporary overload capacity as under shocks and in starting, which no ball bearing has. They are made in the same standardized sizes as ball bearings, in both standard and self-aligning types—some of the latter being wholly enclosed and lubricant-packed. "Hoffmann" Roller Bearings have brought high anti-friction bearing economies into the heavy-duty field where they were never before available.

"NORMA" engineers will welcome an opportunity to work with yours, in applying these high-precision bearings with a view to increased production, greater power savings, and reduced up-keep costs.

THE NORMA COMPANY OF AMERICA

Anable Avenue Long Island City New York

BALL, ROLLER AND THRUST BEARINGS

Power Show BOOTH No. 13 Grand Central Palace – New York, N.Y. December 3rd to 8th

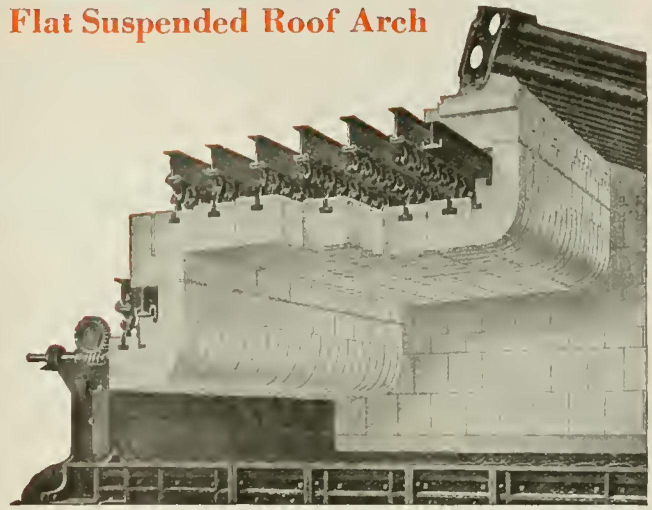
Some of the **STEEL MIXTURE** REG. U.S. PAT. OFF. Money Savers

Veneer Furnace Lining

STEEL MIXTURE Veneer Lining extends inward for only part of the thickness of the fire wall, the rest of which can be built from standard fire brick.

This construction is highly desirable in that the part of the fire wall which gets the least punishment is built from cheaper material and becomes permanent, while the exposed portion can be renewed with less physical effort and with smaller expense for new material. Inasmuch as the destructive influences, even under the severest duty, seldom impair more than the fire surface, the bulk of the fire wall remains intact and uninjured during the reconstruction period, and maintains the strength of the entire wall structure while the veneer surface is being replaced.

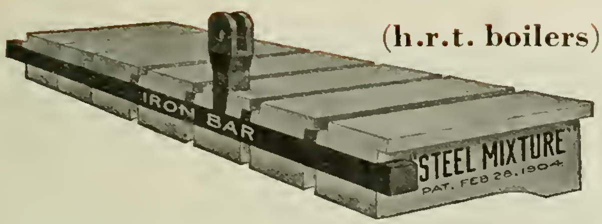
Flat Suspended Roof Arch



Each block independently suspended for easy removal from either *above or underneath* and *without disturbing others.* All blocks hang straight downward and without crushing stresses on their neighbors. Joints of arch with boiler walls are gas-tight and completely cushioned to make expansion harmless. Design flexibility to meet needs of any water-tube boiler or topped furnace.

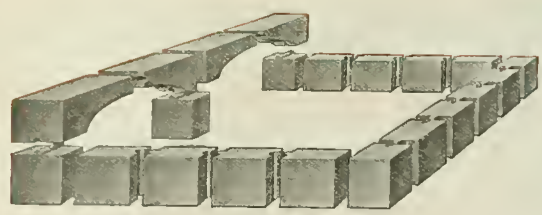
Foote Back-Combustion Chamber Arch

(h.r.t. boilers)



Forms a complete gas-tight cover for the back combustion chamber and protects the flue sheet below the water line. Curved underneath to deflect gases into the flues and gives plenty of room for working with the tubes. Erected in an hour and outlasts the boiler.

Boiler-Door Arches and Fire-Box Blocks



The strongest furnace wall construction that can be put into a boiler. Saves time and labor in erecting and greatly lessens the number of joint corners and edges in the fire surface. Lasts twice as long as small brick. Shortens furnace shut-downs, and assures rigid, well aligned, gas-tight structure. Sizes for any furnace needs and for any number and size of door openings.

Blow-Off Pipe Protection (h. r. t. boilers)

Fitted around or removed from the pipe in a few minutes. Better than masonry piers and the pipe is accessible for inspection.

Roof Arch Blocks

Furnished complete with skew-backs, for any radius from 4 to 10 feet. The fit is always tested before shipment.

Fire Brick

All desirable standard shapes in stock, and specials made for any purpose. Complete or partial refractory equipment for all boilers, metallurgical furnaces, ovens, etc.

Baffle Tile

Shapes and sizes for all popular makes of boilers.

McLEOD & HENRY CO.

Specialists in Furnace Refractories for almost 100 years

Main Office and Works:- Troy, N. Y.

Branches: New York, Boston and Detroit

Power Show BOOTH Nos. 87-88 Grand Central Palace - New York, N.Y. December 3rd to 8th

Model D Electrically Operated Hoist at Liberty Street Telephone Building Boston, Mass.

Densmore and Le Clear Architects

Distance between boiler room floor & grade level is 24 ft. 6 in.

Labor Saving Ash Removal

THE Model D electrically operated Hoist provides a safe, speedy and economical method for ash removal in larger buildings.

The sidewalk opening is completely safeguarded by the G & G sidewalk doors and spring guard gates, which open and close automatically as hoist is raised and lowered.

The overhead crane makes it possible to raise cans directly from boiler room floor to top of truck, and deposit ashes in truck without rehandling at grade.

At the Mergenthaler Linotype Co., Brooklyn, N. Y. (distance between boiler room floor and grade level 12 ft. 0 in.) one of these Hoists was tested for current consumption by Engineers of General Electric Co. It was found capable of raising and lowering 78 cans per k.w.h., or at a money cost of 26 cans for one cent.

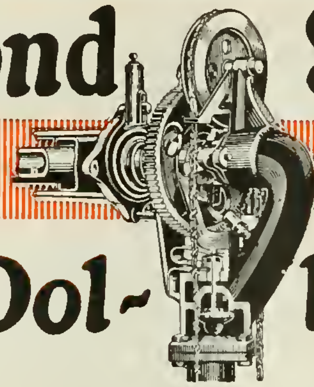
If you will tell us the quantity of ashes you average daily, distance of lift and something about the working conditions of your plant (submit sketch if possible) we will recommend type of hoist to use and give you cost. Illustrated booklet upon request.

At the POWER SHOW, Grsnd Central Palace, New York City, you can see G & G ash removal equipment in actual operation. Don't miss this feature at the Show.

GILLIS & GEOGHEGAN
521 West Broadway New York City

Power Show BOOTH No. 17 Grand Central Palace ~ New York, N.Y. December 3rd to 8th

The Diamond Soot Blower Story in Dol-lars and Cents



HERE is a comparison between blowing a boiler by the hand lance method and by mechanical soot blowers of both the independent valve type and the Valv-in-Head type. A 500 h. p. boiler is assumed, 200 lb. steam pressure, operating at 175 per cent rating, on a basis of the boiler being operated 300 days of 20 hours each per day, with an evaporation of 8 lbs. and a coal cost of $5.50 per ton fired under the boiler. The figures are based on the boiler being blown twice a day with mechanical soot blowers as against once a day with hand lance.

Steam consumption is figured on the basis of each soot blower valve being open a total of 60 seconds each time the boiler is blown in the case of the independent valve blower and 30 seconds in the case of the Valv-in-Head blower. Hand lance steam consumption is figured on a total flow of 20 minutes through a ¾″ nozzle.

Operating Cost per Year with Hand Lance

Steam	$300
Labor (2 hrs. per day)	240
Maintenance	25
	$565

Operating Cost per Year with Mechanical Blowers

	Independent Valve Type	Valv-in-Head
Labor	$ 60	$ 36
Steam	184	92
Interest at 6 per cent	40	45
Depreciation and maintenance 20 per cent	132	148
	$416	$321
Decrease in operating cost due to mechanical blowers	$149	$244

Many actual tests have demonstrated that the savings in fuel effected by mechanical soot blowers over the hand lance run from 2 to 8 per cent.

A boiler operating under the conditions named would consume 10,500 tons of coal in a year's time. Figured at $5.50 a ton, this would amount to $57,700 per year.

1% saving in fuel would amount to $ 577
2% saving in fuel would amount to $1150
3% saving in fuel would amount to $1730
4% saving in fuel would amount to $2310
5% saving in fuel would amount to $2885
6% saving in fuel would amount to $3460

From the above it will be seen that soot blowers commonly pay from 125 per cent to 800 per cent per year on the investment.

Ask for Bulletin 237

DIAMOND POWER SPECIALTY CORPORATION
Detroit-Michigan

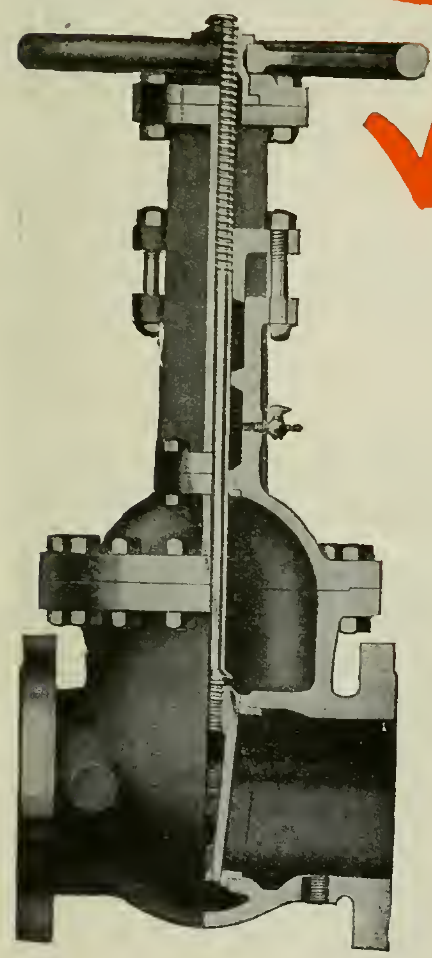
Diamond

Soot Blowers-Save 4 to 8% Fuel

Power Show BOOTH No. 2 Grand Central Palace – New York, N.Y. December 3rd to 8th

CHAPMAN

Guaranteed to 1928!



—to CONTROL Superheated Steam

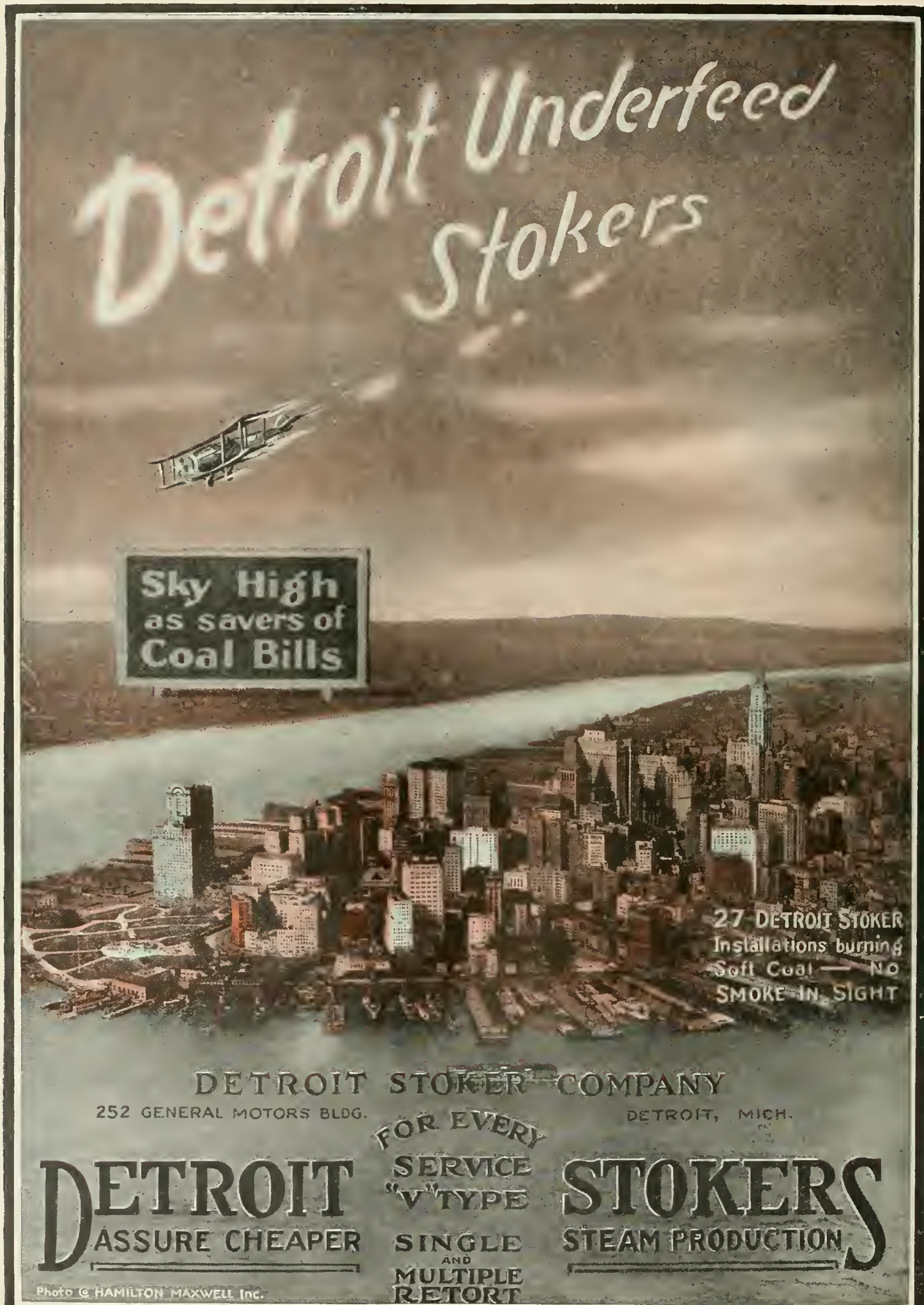
Here is a Cast Steel Gate Valve backed by a definite 5-year GUARANTEE. We can make this guarantee because WE KNOW this Valve. It is built especially for high pressure. Body and cap of cast steel. Spindle of rolled monel. Spindle seats and seat rings of cast monel. And observe the long neck, so designed that the intense heat cannot reach the packing. Ask any man who has installed "List 63½" and we will stand or fall by his say-so, not ours. Fully described in the Chapman Catalog. Send for your copy.

The Chapman Valve Mfg. Company
Indian Orchard, Mass.

BRANCHES:

New York	Pittsburgh	Detroit	Chicago
Boston	Philadelphia	Cleveland	Los Angeles
Tulsa	San Francisco	Houston	Syracuse

VALVES


Detroit Underfeed Stokers
Sky High as savers of Coal Bills
27 DETROIT STOKER Installations burning Soft Coal — No SMOKE IN SIGHT
DETROIT STOKER COMPANY
252 GENERAL MOTORS BLDG.
DETROIT, MICH.
DETROIT ASSURE CHEAPER
FOR EVERY SERVICE "V" TYPE SINGLE AND MULTIPLE RETORT
STOKERS STEAM PRODUCTION
Photo © HAMILTON MAXWELL Inc.


1950
A Message From Mars
"EARTHLY CONTROL BY DEAN SYSTEM"
REMOTE WATER GAUGE
STATION LOAD INDICATORS
REMOTE VALVE CONTROL
SWITCHBOARD
CHIEF ENGINEER
TURBINE AND BOILER ROOMS
PAYNE DEAN LIMITED
STAMFORD, CONN.

Power Show BOOTH No. 74 Grand Central Palace – New York, N.Y. December 3rd to 8th

S & B American Steam Gauge

American Pop-Safety Valve

Generating Power Efficiently and Economically

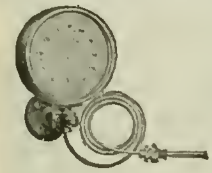
THROUGH the many phases of generating power by steam or water, what is more essential to efficient and economical production than reliable power plant instruments —Valves, Steam Traps, etc.?

The American Schaeffer & Budenberg line is complete and *reliable.* For it is backed by nearly 75 years of practical experience in serving and solving the problems of power generation.

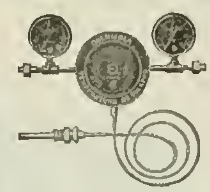
Instruments for indicating, recording and controlling pressures, temperatures and speeds—instruments well known for their accuracy of function and ruggedness and perfection of mechanical construction.

Pop-Safety and Relief Valves of most modern design and of proven adaptability to most severe conditions. A Steam Trap of unusual merit and capacity.

Our Catalog Set N-24 is extremely interesting and instructive. A copy is yours for the asking.



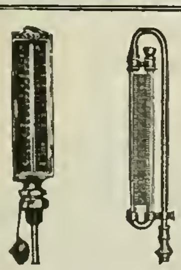
S & B "Reform" Dial Thermometer



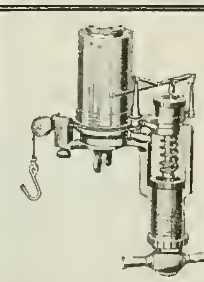
S & B Temperature Regulator

Columbia Recording Gauge

Columbia Recording Thermometer



Crescent Thermometer U Gauge



American-Thompson improved Indicator

American Schaeffer & Budenberg Corporation

SUCCESSORS TO

Schaeffer & Budenberg Mfg. Co.

AND

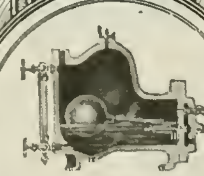
American Steam Gauge & Valve Mfg. Co. Division

Brooklyn, N. Y.

*Boston	Cleveland	New Orleans
Buffalo	Detroit	Philadelphia
*Chicago	*Los Angeles	*Pittsburgh

*Stock carried at these branches

Columbia Hand Tachometer



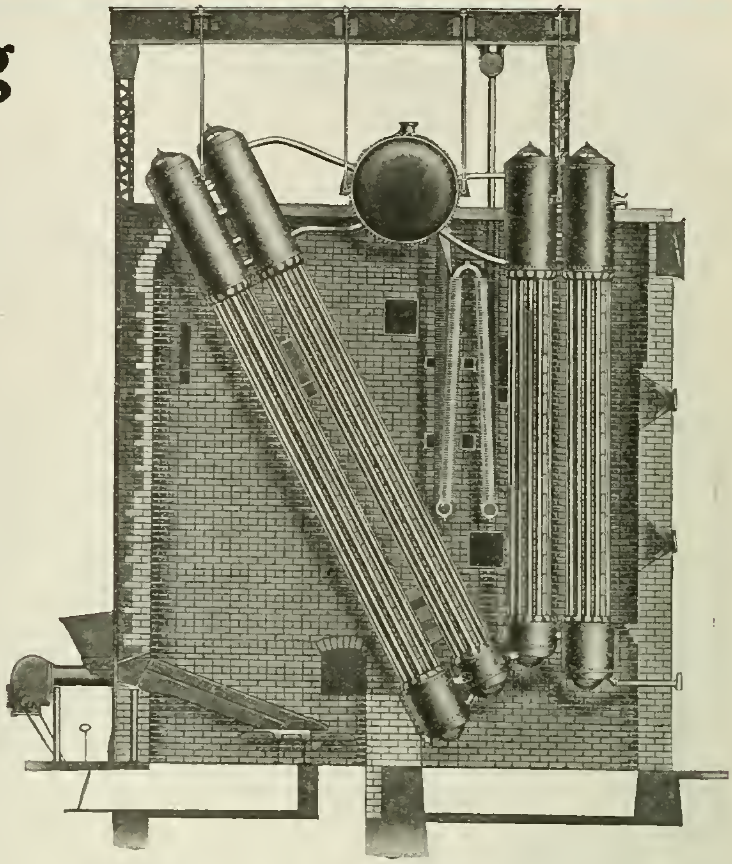
American Ideal Steam Trap

(See Our Data in 1923-24 A.S.M.E. Condensed Catalogues of Mechanical Equipment)

Power Show | BOOTH No. 68 | Grand Central Palace ~ New York, N.Y. December 3rd to 8th

High Operating Efficiency—

Low Repair Cost—



Next to safety—these two features should be your first consideration in selecting the boilers that are most suitable for your plant.

Bigelow-Hornsby Water Tube Boilers

are notable for their excellence in economical steaming.

The scientific design provides for the maximum percentage of direct heating surface, extremely rapid circulation and free steam liberation.

Dry steam at all ratings and high flexibility in meeting all demands promptly are assured.

The gas flow is contrary to the circulation, so that the hottest gases meet the hottest water. The coolest gases are used to preheat the water entering the rear vertical tubes of the boilers. The construction affords ease of access for inspection, cleaning and tube renewals, when required. No tube hand-hole plates or stayed surfaces.

Furnished in units containing from 3750 to 55,000 sq. ft. of heating surface.

Write for illustrated Bigelow-Hornsby Catalog.

BOOTH No. 68

POWER SHOW

Grand Central Palace
New York

DECEMBER 3 to 8, 1923

A complete model of the Bigelow-Hornsby boiler will be on display, under actual working conditions, showing the circulation of water within the boiler and method of gas flow.

The Bigelow Company, 20 Lloyd St., New Haven, Conn.

Boston
141 Milk St.

New York
149 Broadway

Power Show BOOTH No. 44A Grand Central Palace - New York, N.Y. December 3rd to 8th

Increased Boiler Capacity—Constant Steam Pressure *With Cheap Fuel*

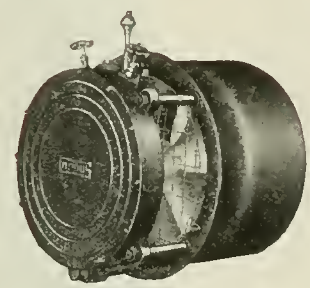
You can carry your heaviest peak load with the cheapest fuel available if you equip your boilers with

COPPUS REGISTERED U.S. PAT. OFFICE

TURBO-BLOWERS

If You Fire by Hand—

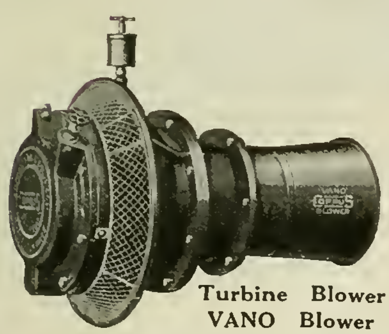
A COPPUS Type "C" Turbo Blower placed in boiler wall will result in a marked saving in fuel and insure higher steaming capacity and steady pressure. It occupies no floor space and is designed for continuous operation under boiler room conditions. Can be controlled automatically or by hand.



Type C Undergrate Blower

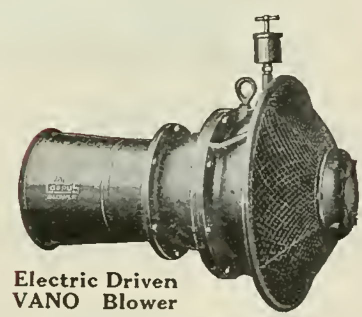
For Mechanical Stokers and Induced Draft—

we have developed the COPPUS VANO BLOWER with either turbine or motor drive.

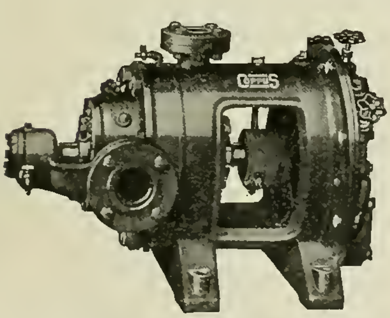


Turbine Blower VANO Blower

The VANO is unquestionably the most efficient blower yet built. It combines the advantages of the centrifugal and propeller blower,—is more efficient than either and admirably adapted for direct motor or turbine drive. Be sure to investigate.



Electric Driven VANO Blower

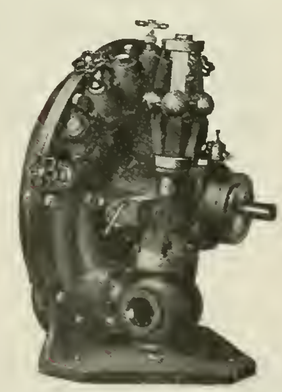


Type TB Coppus Centrifugal Boiler Feed Pumps, multi-stage—the latest development in the feed pump design. Adapted to service with the highest modern boiler pressures.

The Efficient Way To Pump Feed Water

The COPPUS Turbo Feed Pump was specially developed to bring the high efficiency and even feed pressure and other advantages, resulting from the use of centrifugal feed pumps, to the small and medium size plant.

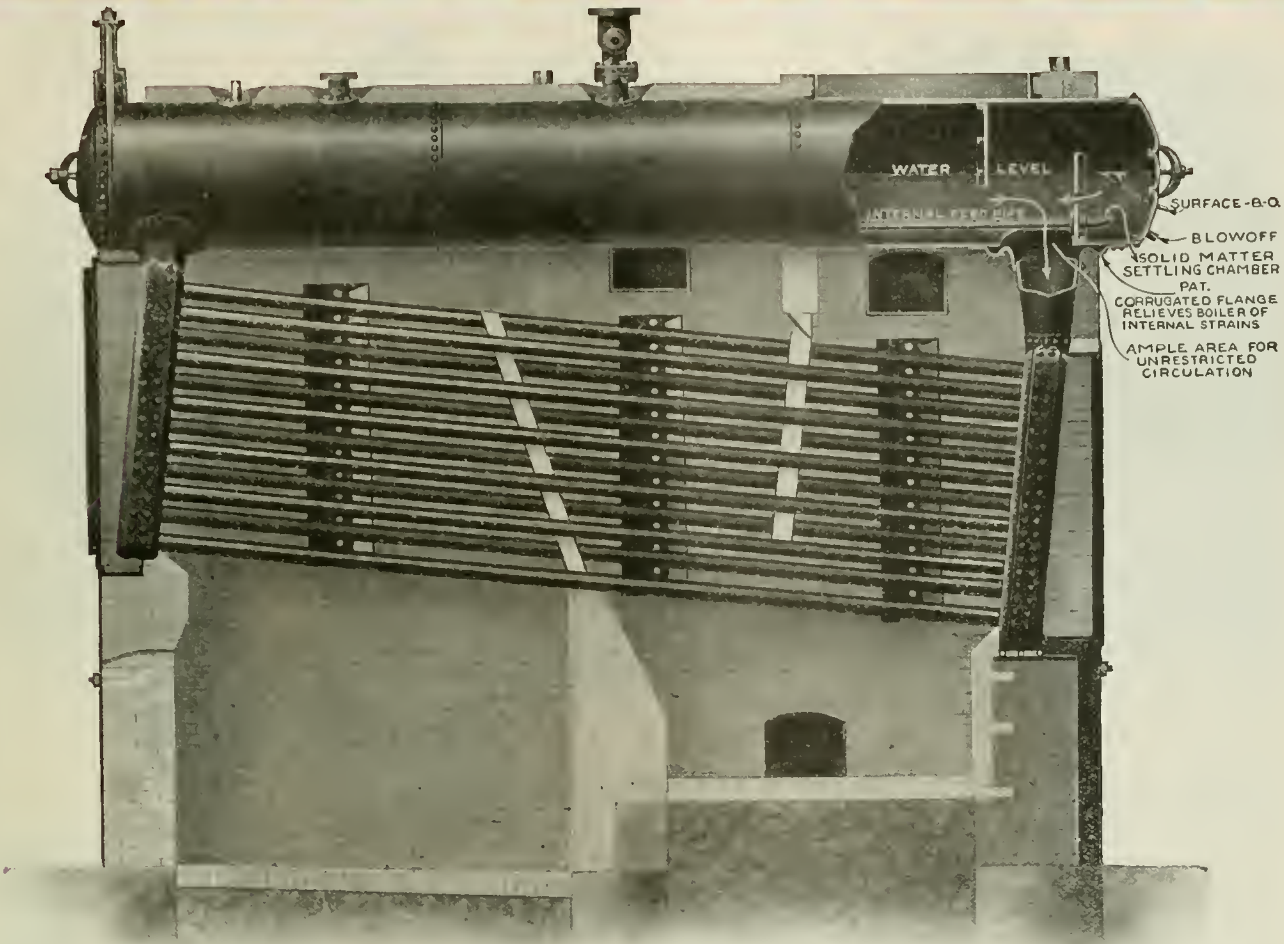
Write us for full set of Coppus Bulletins. Consult us regarding your special requirements.



Type TC Coppus Steam Turbine Two row velocity stage impulse type up to 50 Brake HP.

Coppus Engineering Corp., 342-46 Park Ave., Worcester, Mass.

Power Show BOOTH No. 95A Grand Central Palace ~ New York, N.Y. December 3rd to 8th



UNION WATER TUBE BOILERS

Decidedly Better—For these Reasons

The circulation is faster and more positive—because the wide area headers and connections offer no restrictions to the flow, and the tubes are inclined at an unusually steep angle.

The heating surfaces stay clean, even with bad water, for a considerably longer time—because the feed water must pass through a purifier and settling chamber located in the rear of each drum, where it is out of the path of the fire.

Easier to clean—because the tubes have pear-shaped steel hand hole plates, that are quickly removed and replaced. Vertical staggering of the tubes gives better access for removal of soot.

Scientifically baffled to insure the most efficient gas velocities.

Minimized internal stresses—because the rear header is connected to the drums by means of a flexible corrugated flange.

Headers are made up in integral halves in one heat and thoroughly reinforced by staybolts arranged with a regular pitch. No rivets or double plates are exposed to the fire.

The double drums and the wide area headers give ample water and steam storage space for large overload capacity.

Exceptional care in selecting materials and the best in workmanship insure the highest quality construction that can be put into a boiler.

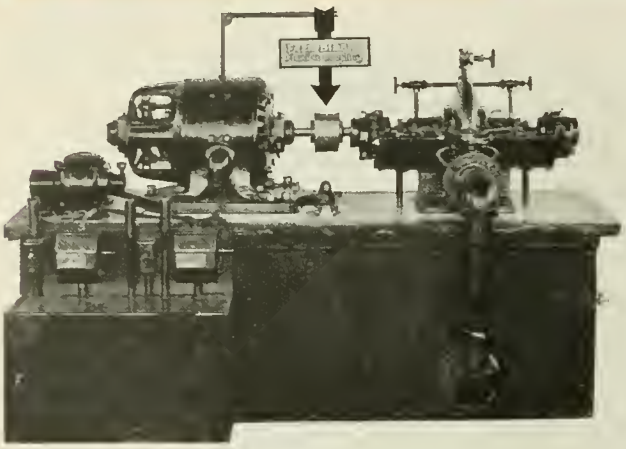
Built in a modern shop at Erie, Pa., located on the main line with unexcelled shipping facilities.

Illustrated Catalog mailed on request. Write for your copy.

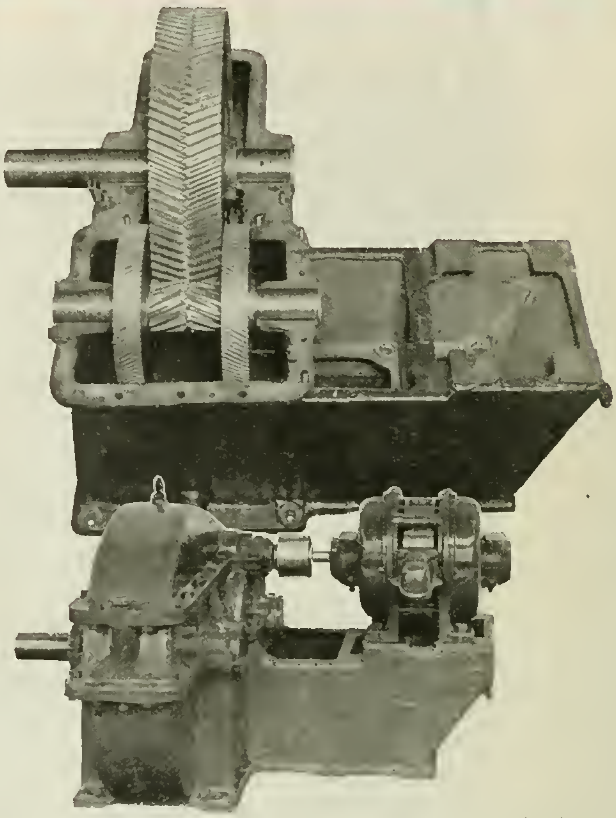
UNION IRON WORKS, ESTABLISHED 1889 Erie, U. S. A.

We also make horizontal return tubular boilers and do steel plate work.

Power Show BOOTH No. 339 Grand Central Palace - New York, N.Y. December 3rd to 8th



This interesting demonstration which will be shown at the Power Show in New York, discloses the fact that the Falk-Bibby Coupling has extraordinary capacity for angular misalignment. It consists of a single stage centrifugal pump to provide load with a number 4.5 Falk-Bibby Coupling attached to a motor which is set on a sliding base pivoted at the front and rear ends. This allows for continuous movement from side to side through a total angle of 6 degrees with the aid of a small auxiliary motor, worm gear and adjustable crank. This shows conclusively that the coupling can accomodate an actual misalignment of 3 degrees.



Two Plane Type Double Reduction Herringbone Gear Unit to be exhibited at the Power Show—Ratios 40 to 50 to 1—5 H.P.—1150 to 23 r.p.m. Designed for Saw Mill work.

Falk-Bibby Flexible Couplings now mean in the alignment of shafting what Falk Herringbone Gears have long meant in transmitting power.

The placing of this coupling—(which has both torsional and lateral elasticity and which remains truly flexible under normal and light loads and will stand far greater overloads than any other type)—on the American Market is a notable step in the consummation of a complete Falk Service for the smoothest and most efficient distribution of power which can be attained.

Do not fail to visit us in Booth 339.

THE FALK CORPORATION

Milwaukee Wisconsin

REPRESENTATIVES:

W. O. Beyer, 1007 Park Bldg., Pittsburgh, Pa.

Mine & Smelter Supply Co., Denver, El Paso and Salt Lake City.

M. P. Fillingham, 50 Church St., New York City.

Engineering Equipment Co., Ltd., 358 Beaver Hall Square, Montreal, Quebec, Canada.

Vulcan Iron Works, Wilkes-Barre, Pa.

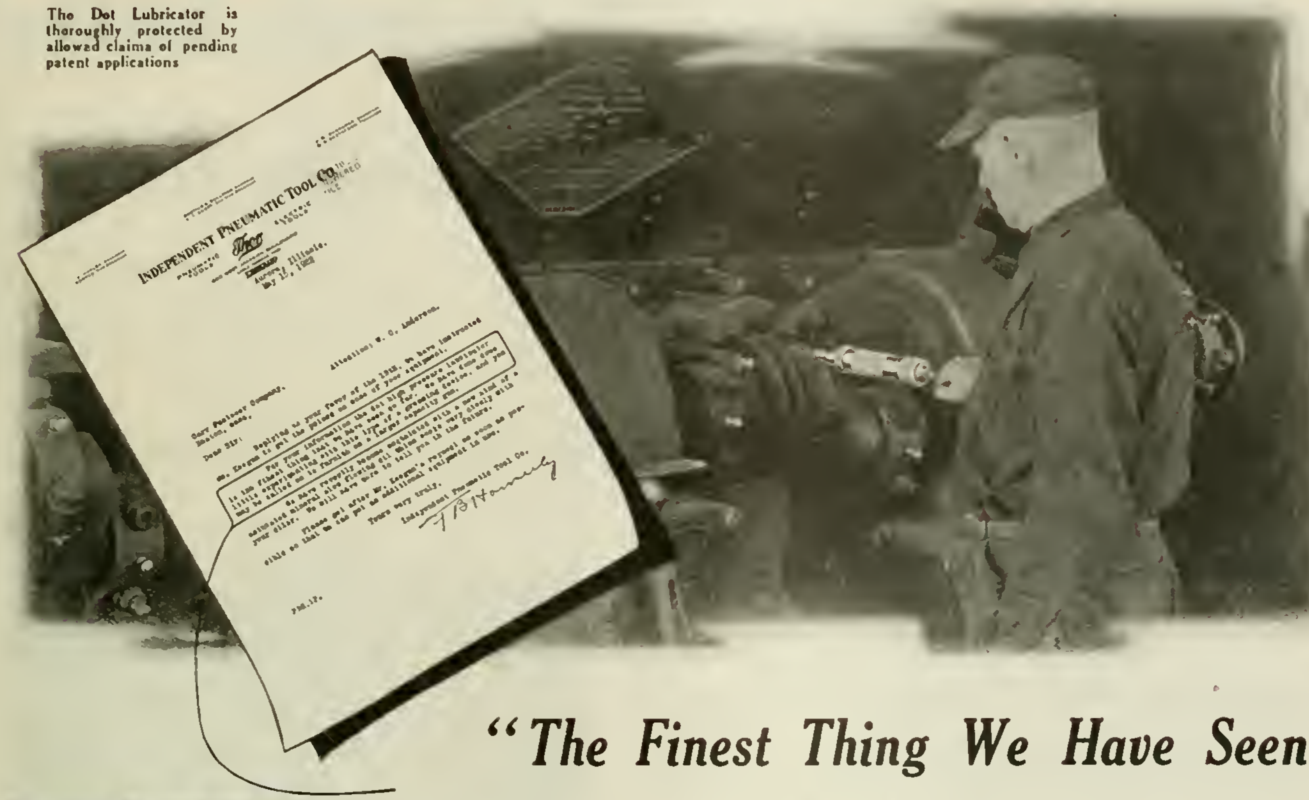
General Machinery Co., Brown Marx Bldg., Birmingham, Ala.

FOREIGN REPRESENTATIVES: Gustav Melms, 3 Rue Taitbout, Paris.

FALK

Power Show BOOTH No. 236 Grand Central Palace - New York, N.Y. December 3rd to 8th

The Dot Lubricator is thoroughly protected by allowed claims of pending patent applications



"The Finest Thing We Have Seen"

—writes the Works Manager of the Independent Pneumatic Tool Co., Aurora, Ill. Innumerable letters from enthusiastic users of the DOT give concrete evidence of the successs of the DOT System for lubricating industrial machinery.

Lubricating and maintenance costs have been lowered, frozen bearings, break-downs and costly delays have been avoided and depreciation of machinery has been considerably reduced by the installation and use of the DOT High Pressure System. Manufacturers who are proud of the machinery they make will see immediately how standard adoption of the DOT wins prestige and good will for their firms and enhances the value of their products.

ABOVE—Showing Solid, direct connection of nozzle to steel, one-piece nipple. Nozzle locks tight on nipple, forming a leak-proof seal. The greater the pressure the tighter the seal.

Used as Standard Equipment by More Than 100 Leading Industries in America

Why the "DOT" Succeeds Where Others Fail

In the above letter the writer says—"A new kind of saturated slow-flowing mineral oil works very nicely with the Dot." That is one of the exclusive features of the Dot. The automatic valve and solid leak-proof connection of nozzle and nipple enables it to handle oil as well as grease or kerosene for flushing frozen bearings. *With a progressive pressure from 1 to 3000 pounds*, it forces out gritty, gummed-up grease, replacing it with good, clean lubricant. Operated entirely with one hand, it is clean, convenient and *safe* to handle. The oiler can stand well away from pulleys, belts, gears, and other danger spots and still reach each lubricating point with perfect ease. For very remote parts, such as between two closely-located machines or bearings located beyond ordinary reach "extension arms" are provided.

The Dot "Knapsack" carrier and gun for lubricating a large number of machines, pulleys, etc.

An interview may mean large savings to you in the elimination of costly lubricating difficulties.

MADE ONLY BY

CARR FASTENER COMPANY 31 AMES STREET Cambridge, Mass.

"Makers of the DOT Line of Fasteners"

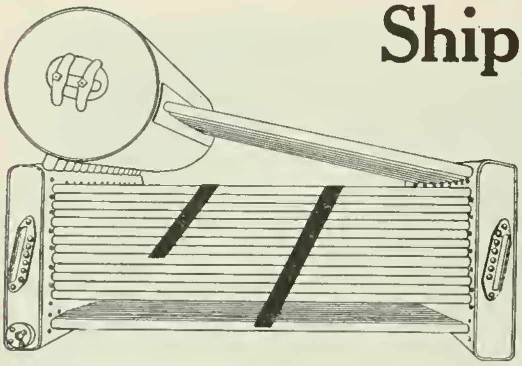
BRANCHES:

40 Seldon Ave. Detroit — 47 W. 34th St., New York City — Monadnock Bldg., San Francisco — Gage Ave. & Beach Road Hamilton, Ont., Canada

Be Sure to Visit Booth No. 236 when at the Power Show

·DOT *high pressure* **LUBRICATOR**

Power Show BOOTH No. 95 Grand Central Palace - New York, N.Y. December 3rd to 8th



Shipped Completely Baffled

WITH

"Mono" (TRADE MARK) Boiler Baffles

The illustration shows one of twelve Heine Cross-Drum Boilers fitted with "**Mono**" baffles built in their shop and shipped by rail as complete units to Staten Island for installation on board the new municipal ferry-boats in New York Harbor.

"MONO" BAFFLES WITHSTAND VIBRATION

and are the most economical to install because of their long, lasting qualities. **"Hugs the Tubes"** and permits any tube to be withdrawn and replaced without injury to the baffles.

We guarantee **"Mono" Baffles** to withstand the use of an air driven turbine cleaner, the shock, vibration and other abuse of handling.

OUR MANY SATISFIED CUSTOMERS PROVE THESE STATEMENTS

"Mono" Baffles are installed by us or **You can Build Them with "Mono" Cement** following our instructions.

Our engineers are ready to serve you.

The illustration above shows a first-pass "Mono" baffle as seen through an opening in the side wall, looking toward the rear of the boiler. Note the absolutely monolithic construction—the close fit around tubes and against the walls—and the entire freedom from any possibility of leakage.

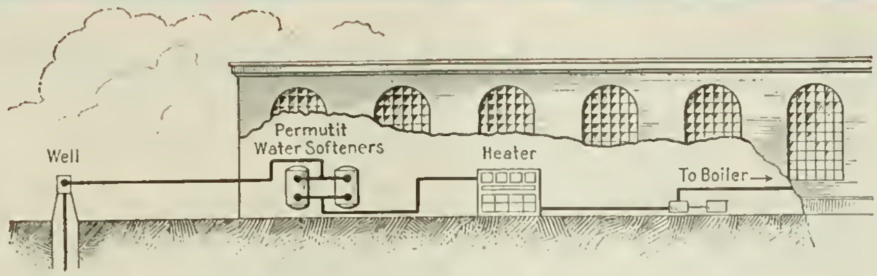
Write for Bulletin M

KING REFRACTORIES CO., Inc.

BUFFALO, N. Y.

Boston | New York City | Philadelphia | Chicago
Pittsburgh | Cleveland | Cincinnati | Detroit
Toronto, Canada, Grant E. Cole Co.

Power Show BOOTH No. 3 Grand Central Palace - New York, N.Y. December 3rd to 8th



How a New Jersey Engineer Keeps his Boilers free from Scale

The Chief Engineer of a water supply company in New Jersey operates a boiler plant consisting of 1 Erie, and 2 Babcock and Wilcox water tube boilers, totalling 435 H.P. The feed water, as obtained from their well, contains only 6 grains of hardness per gallon, but nevertheless, the Chief Engineer writes that he formerly had "endless trouble with scale." He tried boiler compounds of all sorts, but was not successful in preventing scale or relieving the constant, difficult cleaning it causes.

Previous to 1916 he had only one Erie boiler, of the three boilers mentioned above. He thoroughly investigated scale prevention and was so convinced he was on the right track that when the two new B & W boilers went in, he also installed a Permutit Water Softener to remove all scale-forming impurities from the total feed water of 24,000 gallons per 24 hours.

Starting with 2 new boilers, he had an excellent chance to observe the work of the Softener. And this is what he writes:

January 18th, 1923.

"Before installing our Permutit Water Softener (in December 1916), we had endless trouble with boiler scale. At that time, we installed two Babcock boilers. Up to the present time, the Babcock boilers are ***as clean as the day they were installed.*** * * * We have used a number of boiler compounds, but find your Softener is the only treatment that has given satisfaction. We consider this method of water softening 100% perfect."

(Copy of this letter and name of Company gladly furnished upon request.)

After six years, his boilers are as clean as the day they were installed. Think what it would mean to you to have your boilers ***stay*** clean—and we can solve your problem equally well.

This Chief Engineer got his original suggestions from our booklet, "Reducing Fuel and Boiler Plant Operating Costs," which contains a clear explanation of the causes of scale and how to prevent it, as well as first-hand data which we have collected from engineers in the hundreds of plants we have served.

You will find it very interesting and instructive—just mail the attached coupon today for a copy.

The Permutit Company
440 Fourth Ave. New York

For Your Protection

On June 15, 1921, the Federal Court at Buffalo (Hazel, J.) handed down a decision sustaining our patent covering zeolite water softening apparatus, and stating that this patent "is concededly not limited to any particular class of zeolitic material." The Court also described the apparatus held to infringe, and this description, our counsel advises, applies to all zeolite softeners on the market. Other suits brought by us for infringement are pending.

The above decision has been affirmed by the Circuit Court of Appeals, and the U. S. Supreme Court has denied a petition for a writ of Certiorari to review it.

See Our Data in 1923-24 A.S.M.E. CONDENSED CATALOGUES of MECHANICAL EQUIPMENT

Send for this free booklet

The Permutit Company
440 Fourth Ave.
New York

Please send me your free booklet, "Reducing Fuel and Boiler Plant Operating Costs."

Name ....

Address ....

....

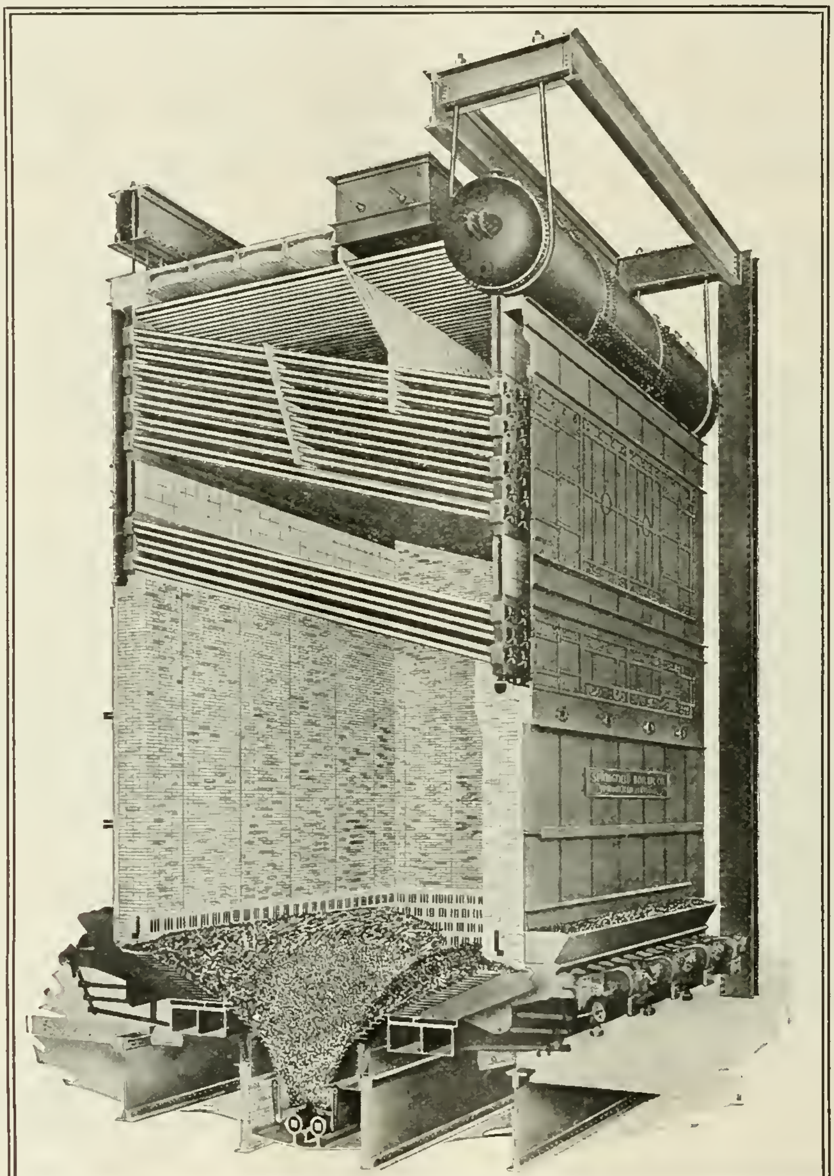
Company ....

2028-31

Power Show BOOTH No. 31 Grand Central Palace – New York, N.Y. December 3rd to 8th

SPRINGFIELD BOILERS
IN THE HELL GATE STATION
of the United Electric Light & Power Co., New York City

SECTIONAL ALL STEEL



NO STAY BOLTS NO BENT TUBES

In 1920—The United Electric Light & Power Co.—purchased and installed 12—1890 H.P. Springfield Boilers for their new Hell Gate station.

Three additional Springfield Boilers are now being installed in the Hell Gate Station and six in the Sherman Creek Station of the above Company.

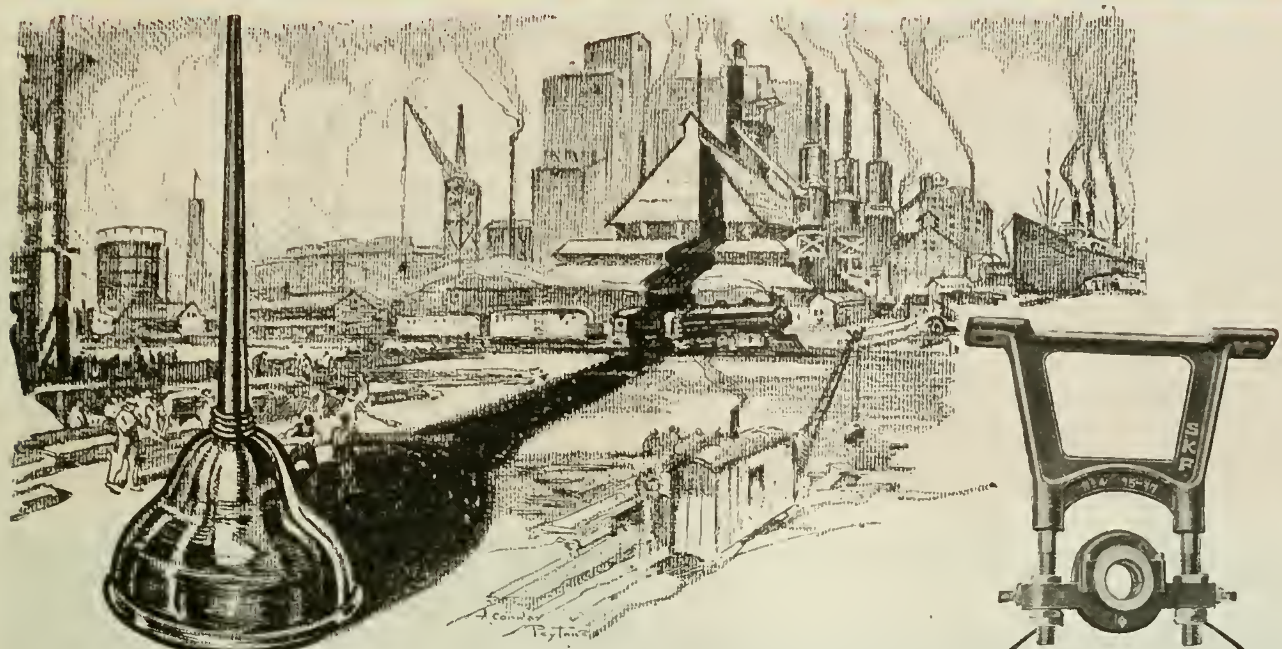
Large Power users and leading Engineers purchase Springfield boilers *again and again.*

SPRINGFIELD BOILER CO.
SPRINGFIELD, ILL.

OFFICES:

Chicago	Detroit
Boston	Buffalo
New York	Duluth
Philadelphia	Minneapolis
Pittsburgh	Atlanta
Richmond	Kansas City
Cleveland	Denver
Cincinnati	San Francisco

Power Show BOOTH Nos. 332-333 Grand Central Palace — New York, N.Y. December 3rd to 8th



Is the shadow of the oil can on your plant?

ARE you dependent upon the oil can and the handy man to keep your plant going—to prevent hot bearings and other troubles which curtail production and eat into your profits?

Remove the shadow of the oil can from your plant by installing Skayef self-aligning ball-bearing hangers which will not bind and heat. Lubricant and maintenance charges will be reduced 60 to 80 per cent and you can release the handy man for more profitable work. A little lubricant once every three or four months is all the attention this type of hanger requires.

Others have found that ball-bearing equipment pays for itself in two years and often in a shorter period. Let an SKF engineer estimate what you will save.

1066 *For Nearest Distributor See McRae's Blue Book.*

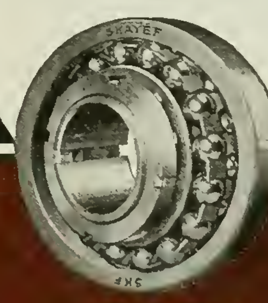
SKAYEF
—the 4-Saving Hanger

1st Saving Skayef Hangers save from 50 per cent upward of the energy which plain bearings consume in friction. This means a saving of 15 to 35 per cent of your power cost.

2nd Saving Considerable time is saved by eliminating shutdowns for replacing or adjusting bearings; forced idleness of machines and men is a cost-factor too big to be ignored.

3rd Saving Lubricant consumption reduced 60 to 80 per cent as compared with plain bearing hangers. Lubricant required only at infrequent intervals and it cannot leak out and ruin belts or product.

4th Saving There is no discernible wear of the hard steel balls and races and absolutely no shaft wear. Dust and grit cannot enter the bearings and Skayef self aligning ball-bearings have the exclusive inherent ability of compensating automatically for shaft deflections.



SKAYEF
Self-Aligning Ball-Bearing
HANGERS

Made Under **SKF** *Supervision*

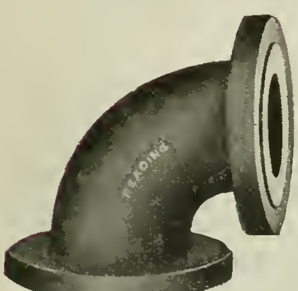
THE SKAYEF BALL BEARING COMPANY . . . . 165 Broadway, New York City

Power Show BOOTH No. 48 Grand Central Palace—New York, N.Y. December 3rd to 8th

READING CAST STEEL FLANGES and FITTINGS

Working Pressure Classifications

Extra Heavy Cast Steel Flanged Fittings for 350 lbs. working pressure at 800° F.



Standard Cast Steel Flanged Fittings for 250 lbs. working pressure at 800° F.

Class B

Steam or oil up to 150 pounds pressure and temperatures up to 800° Fahrenheit. Cold water or oil up to 300 pounds pressure.

Class F

Steam or oil up to 250 pounds pressure and temperatures up to 800° Fahrenheit. Cold water or oil up to 500 pounds pressure.

Class H

Steam or oil up to 350 pounds pressure and temperatures up to 800° Fahrenheit. Cold water or oil up to 700 pounds pressure.

Class L

Steam or oil up to 500 pounds pressure and temperatures up to 800° Fahrenheit. Cold water or oil up to 1000 pounds pressure.

Class N

Steam or oil up to 750 pounds pressure and temperatures up to 800° Fahrenheit. Cold water or oil up to 1500 pounds pressure.

Class T

Steam or oil up to 1500 pounds pressure and temperatures up to 800° Fahrenheit. Cold water or oil up to 3000 pounds pressure.

Hydraulic Cast Steel Flanged Fittings for the higher steam pressures.

Screwed Cast Steel Fittings for all pressures and temperatures up to 800° F.

READING STEEL CASTING COMPANY

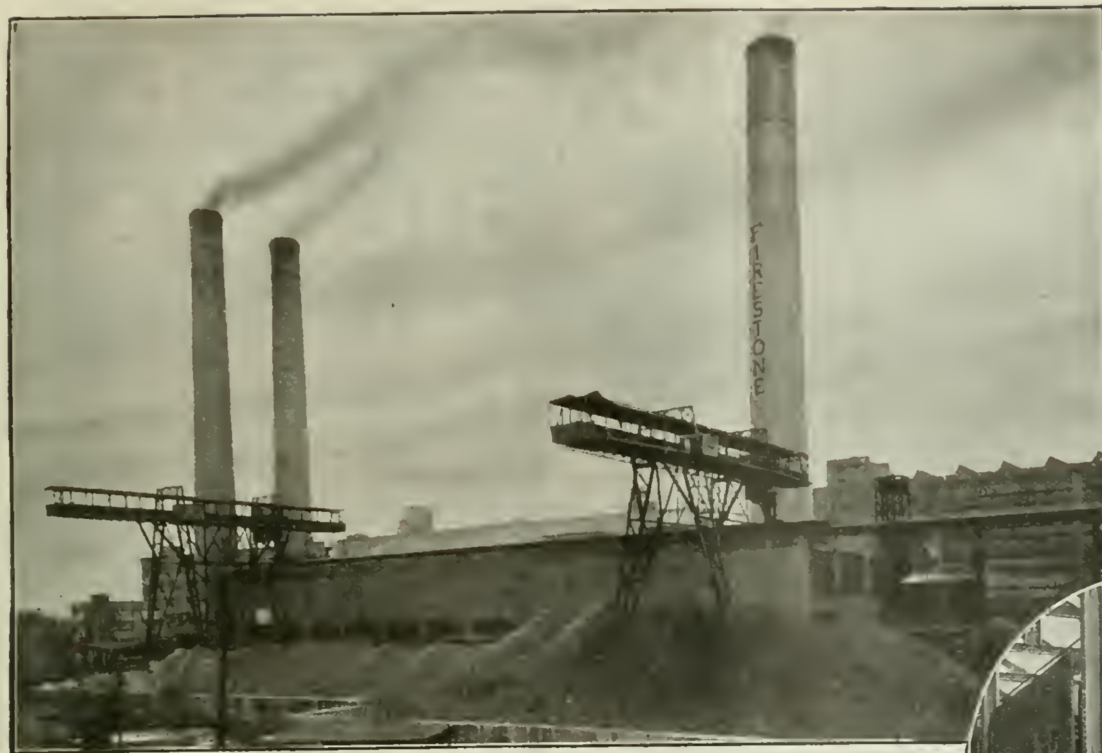
INCORPORATED

Reading Valve & Fittings Division

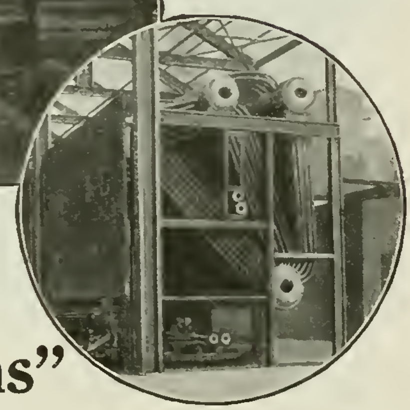
An Associate Company of the American Chain Company, Incorporated

929 Connecticut Ave. Bridgeport, Conn.

Boston, Charlotte, Chicago, Cleveland, Detroit, Hartford, Houston, New York, Philadelphia, Pittsburgh, San Francisco, St. Paul, Rochester



Power plant of Firestone Tire & Rubber Co., Akron, Ohio, operating four 1107 H. P. Connelly water tube boilers.



"Particularly Successful Under High Overload Conditions"

THE power generating equipment for manufacturing plants whose variable production conditions sometimes require its operation far above rated capacity must be selected with special care.

Thus the provision for delivering dry steam at high overload capacity furnished by the special design of Connelly (patented) water tube boilers naturally appealed to the builders of tires designed to give "most miles per dollar."

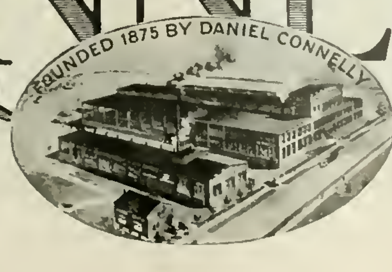
Since the installation of four 1107 H.P. Connelly boilers, Firestone has had no difficulty in getting 250% of rating and has even obtained a higher percentage on occasion, though their stack draft is not sufficient to operate above that point on balanced draft.

As Connelly boilers are built in units of from 200 to 3000 H. P. and for steam pressures up to 350 lbs., this economical equipment is equally serviceable for either large or small requirements.

A fully explanatory catalog will gladly be sent at your request

The Connelly Boiler Company

1170 Ivanhoe Rd. Cleveland Ohio



See Our Exhibit
at the
POWER SHOW
December 3rd to 8th
Grand Central Palace
New York

THE GEORGE T. LADD COMPANY
Manufacturers of LADD WATER TUBE BOILERS
First National Bank Building, Pittsburgh, Penna.

Chicago Office MCCORMICK BLDG. Philadelphia Office Franklin Bank Bldg. New York Office 18 Warren St.

See Our Data in 1923-24 A.S.M.E. Condensed Catalogues of Mechanical Equipment

Cole-Manning Vertical Fire-Tube Boilers

This type of boiler is constructed in units up to 400 horse-power and for pressure of 200 lbs. or more. Boiler shell is supported on a one-piece cast iron base which can be fitted with stationary or shaking grates. Smoke box is provided with removable cast iron cover and connections for all standard soot-cleaning devices. The evaporative performance, super-heating qualities and small floor space per horse power combine to make a most desirable and economical unit.

Further information regarding Cole Boilers, Tanks, Plate Work, etc., will be found on page 52 of the 1923-24 volume, A.S.M.E. Condensed Catalogues.

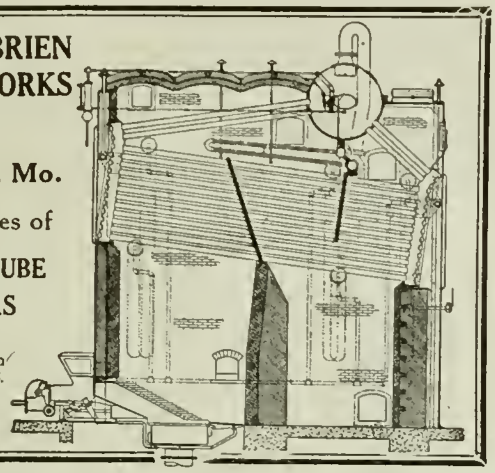
R. D. Cole Manufacturing Co. Newnan, Ga.

JOHN O'BRIEN BOILER WORKS CO.

St. Louis, Mo.

Four Types of

WATER TUBE BOILERS

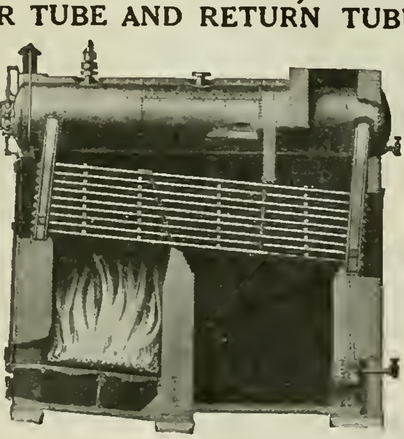


See Our Data in 1923-24 A.S.M.E. CONDENSED CATALOGUES

MECHANICAL ENGINEERING

November, 1923 CARD INDEX Vol. 45, No. 11

KEELER
BOILERS,
WATER TUBE AND RETURN TUBULAR

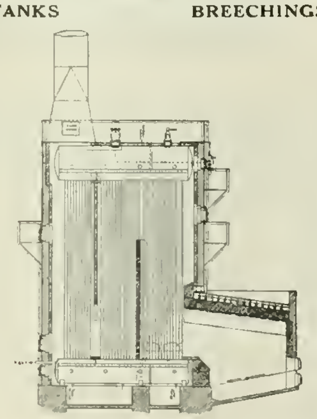


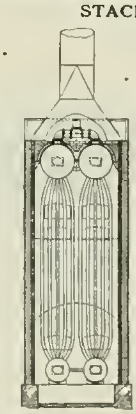
ARE RELIABLE AND SAFE
No Keeler boiler has ever exploded.
ECONOMICAL: cost of upkeep phenominally low.
EFFICIENT: numerous tests tell.
Catalog of either type on request.

E. KEELER CO., Williamsport, Penna.
BRANCHES: NEW YORK PHILA. BOSTON BUFFALO PITTSBURGH CHICAGO

See Our Data in 1923-24 A.S.M.E. Condensed Catalogues of Mechanical Equipment

TANKS BREECHINGS STACKS



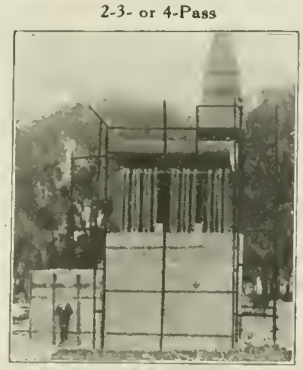


2-3- or 4-Pass

Lasting efficiency

Unimpeded circulation

Write for catalog



Baffles are self-supporting

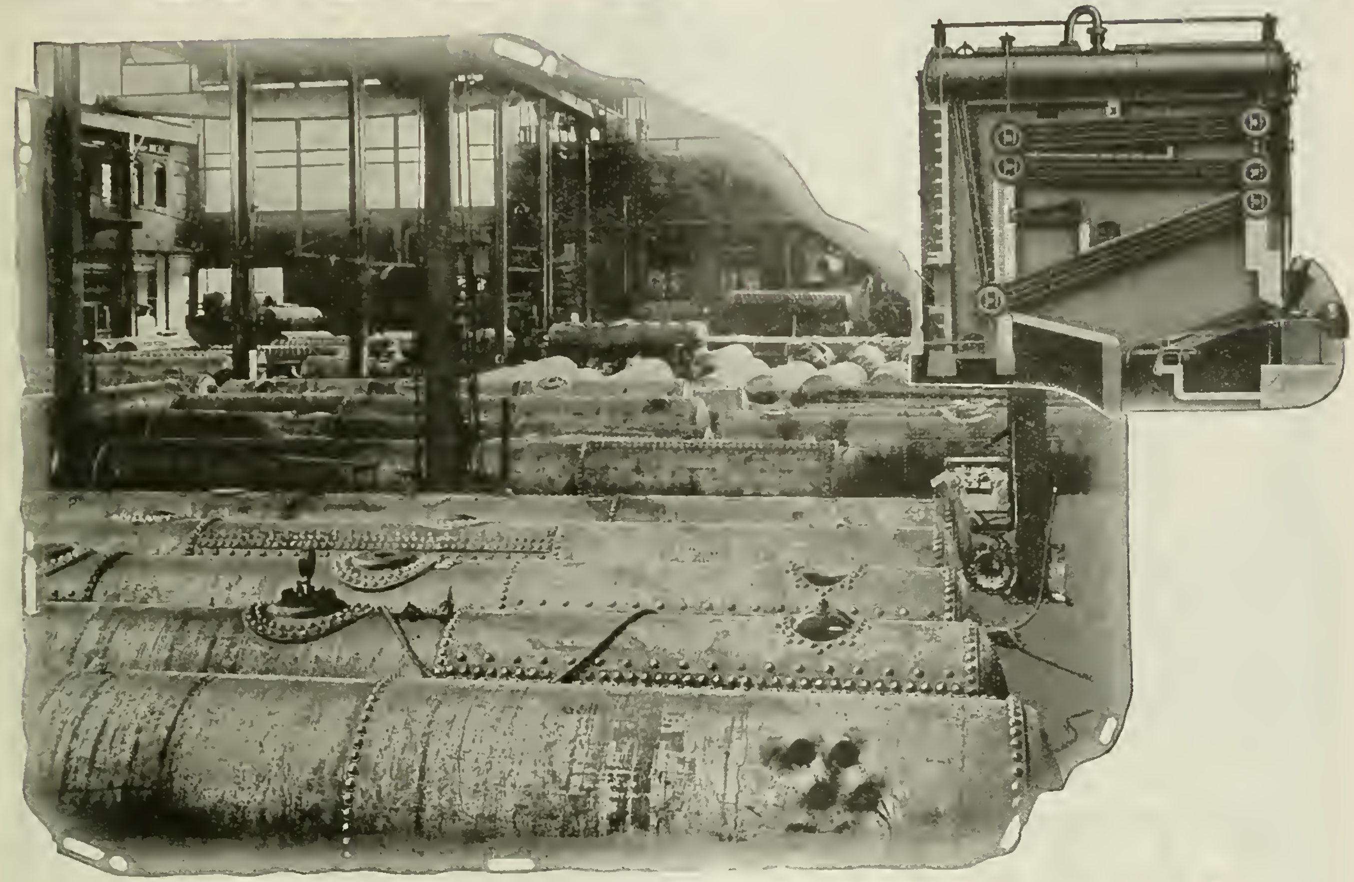
Fool-proof baffles

No "special" parts

Send your inquiry

MORRISON BOILER CO.
CLEVELAND, OHIO

PRODUCTION



Vogt Water Tube BOILERS

GREATEST VALUE PER DOLLAR—that is what you get when you purchase the better built Vogt Water Tube Boilers.

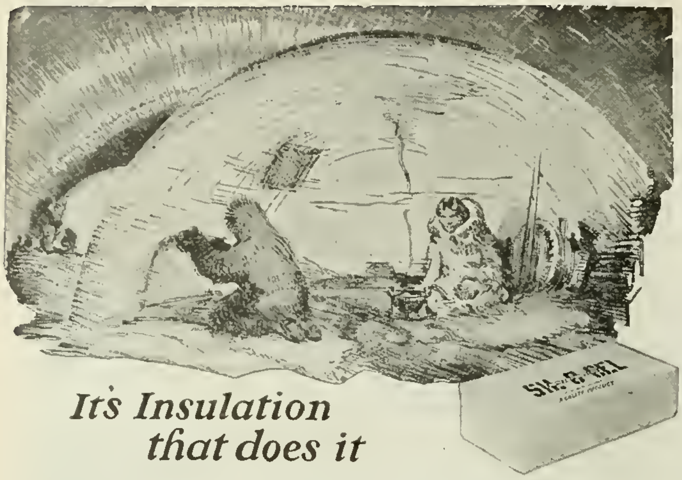
Large scale production as illustrated here reduces our cost to a minimum and enables us to give you maximum value per dollar.

Write For Bulletin W T-2

Henry Vogt Machine Co.
INCORPORATED
LOUISVILLE, KENTUCKY

BRANCH OFFICES: NEW YORK, CHICAGO, PHILADELPHIA, DALLAS

MANUFACTURERS OF
WATER TUBE AND HORIZONTAL RETURN TUBULAR BOILERS :: :: DROP FORGED STEEL VALVES AND FITTINGS
OIL REFINERY EQUIPMENT :: :: ICE-MAKING AND REFRIGERATING MACHINERY



It's Insulation that does it

A TINY FLAME keeps the Eskimo's igloo warm and comfortable, despite the fact that the outside temperature may be many degrees below zero.

It's insulation that does it. Millions of microscopic air cells formed between the particles of tightly packed snow break up heat penetration and hold it within the hut. Large air spaces are not as effective, as the U. S. Bureau of Standards have decisively proved, and the perfect heat insulation only needs in addition to its countless minute air cells, a composition which withstands high temperatures, and sufficient structural strength.

All these requirements are found in SIL-O-CEL Heat Insulation—in world-wide service on all types of high temperature equipment. Tests by the Bureau of Standards prove it to possess a lower heat conductivity than any other insulation suitable for high temperatures. Furnished in forms which withstand without shrinkage, direct heats of 2000° F., SIL-O-CEL has ample structural strength, is easily applied and permanently effective.

A type for application to boilers, furnaces, ovens, kilns and similar heated units without change in design — Brick, C-22, Block, C-3, Powder, Cement.

Write nearest office for complete information given in Bulletin H-6C, or mail the coupon.

A CORRECTION
The crushing strength of SIL-O-CEL Insulating Brick was incorrectly reported in last month's advertisement as being 400 lbs. per square foot. This should read "400 lbs. per square *inch*" or 28 tons per square foot.

BARRIERS TO INDUSTRIAL WASTE
SIL-O-CEL
FILTER-CEL
CELCOTE
FRAXITE

CELITE PRODUCTS COMPANY
New York-11 Broadway Chicago-53 W. Jackson Blvd. San Francisco-Monadnock Bldg.
Offices and Warehouses in Principal Cities
CELITE PRODUCTS LIMITED, New Birks Bldg., Montreal, Canada
CELITE PRODUCTS CORPORATION, Windsor House, London, S.W.1., England

CELITE PRODUCTS COMPANY—
Gentlemen: Send blueprints and Bulletin H-6C on SIL-O-CEL
Heat Insulation for ______________
(Give type of equipment)
Name ______________
Company ______________
Address ______________

DURA-STIX

BONDS the Boiler Settings in the best known plants of America

OUTLASTS fire-clay ***FOUR*** times. Try **DURA-STIX** and be convinced.

Booklet EM tells how

Keystone Refractories Company
120 Liberty St., New York

Use your Old Fire Brick

You can crush your old linings and mix the crushed material with

HYTEMPITE

TO REBUILD YOUR SETTINGS

Note this sidewall section. Large power plants are using this method because it

Prevents Infiltration **Saves Fuel, and**
Reduces Radiation **Reduces Maintenance cost**

Booklet H-109-M tells how

See Our Data in 1923-24 A.S.M.E. Condensed Catalogues of Mechanical Equipment

Hytempite is carried in stock in every industrial center for immediate delivery

QUIGLEY FURNACE SPECIALTIES CO., Inc.
26 Cortlandt St. New York

NEGUS-TIFFANY COAL AGITATORS

WILL CURE YOUR WET COAL TROUBLES

and increase boiler efficiency at all times

Saves Coal
Saves Labor
Saves Breakage
Saves Money
Saves Cussing

W. E. ELLIS CO.
Haverhill, Mass.

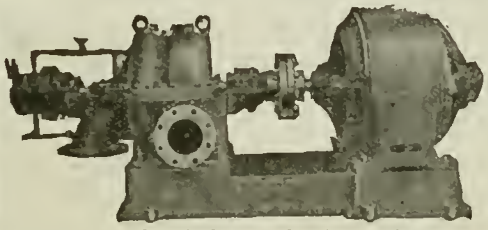
STOKERS

Builders of Mechanical Stokers for 35 years
Sales and Service Offices in All Principal Cities
Address Nearest Office
Westinghouse Electric & Mfg. Co.
So. Philadelphia Works, Philadelphia, Pa.

WESTINGHOUSE ELECTRIC

Westinghouse

On the Job with MORRIS



Horizontally Split Multi-Stage Pump

This type of pump is needed when operating under high heads and pressures, such as supplying water to hydraulic giants, etc. It is especially adapted for high efficiency and for operating at high speed. Suction and discharge openings are in the bottom half of the shell, therefore top can be removed without disconnecting them. Write for Bulletin No. 19A-1.

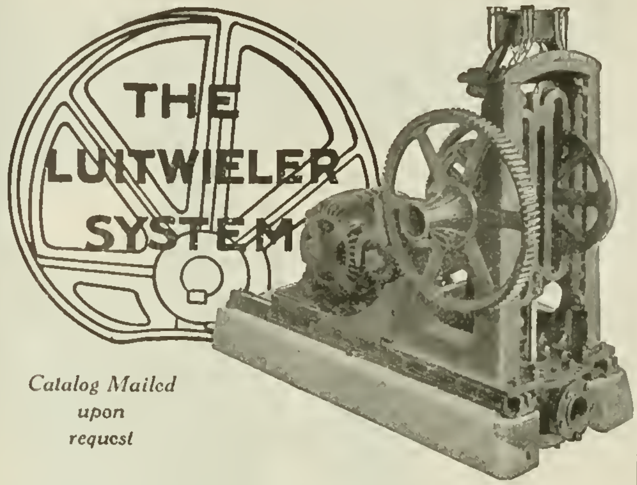
See Our Data in 1923-24 A.S.M.E. Condensed Catalogues of Mechanical Equipment.

Boston, Mass. 79 Milk St.	Detroit, Mich. Penobscot Bldg.	Charlotte, N. C. Realty Bldg.
New York 39-41 Cortland St.	Cleveland Engineers Bldg.	Chicago 217 N. Jefferson St.

Philadelphia, Pa., Forrest Bldg.

Since 1864 Builders of Dredges Centrifugal Pumps Steam Engines

MORRIS MACHINE WORKS BALDWINSVILLE, N.Y. BRANCH OFFICES IN PRINCIPAL CITIES



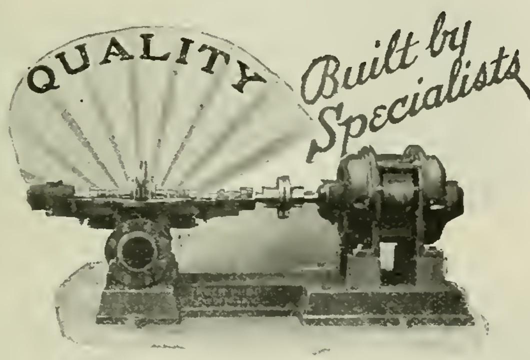
Catalog Mailed upon request

Reciprocating Cams and Balanced Parts are the basis for High Efficiency of—

LUITWIELER
Non-Pulsating Deep Well Pumps

For Automatic Electric and Hydro-Pneumatic Pressure Water - Systems Deep Well and Pressure Pumps.

Luitwieler Pumping Engine Co.
123 Ames St., Rochester, N. Y.

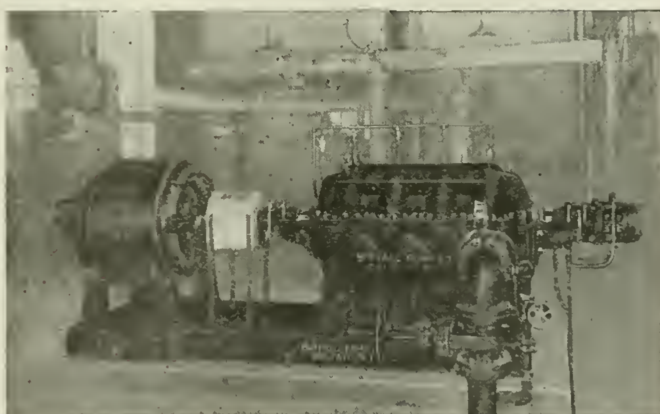


THE "vitals" of every Taber Pump reveal built-in quality; every construction detail receives careful, expert attention. The result is a pump that gives complete satisfaction in operation.

Taber Pumps are built to suit your particular needs. Submit *your* problems to us.

Illustration: "Vitals" of Taber S-L Double Suction Centrifugal Pump, bronze fitted.

TABER PUMP CO. Buffalo, N.Y.
Pump Specialists

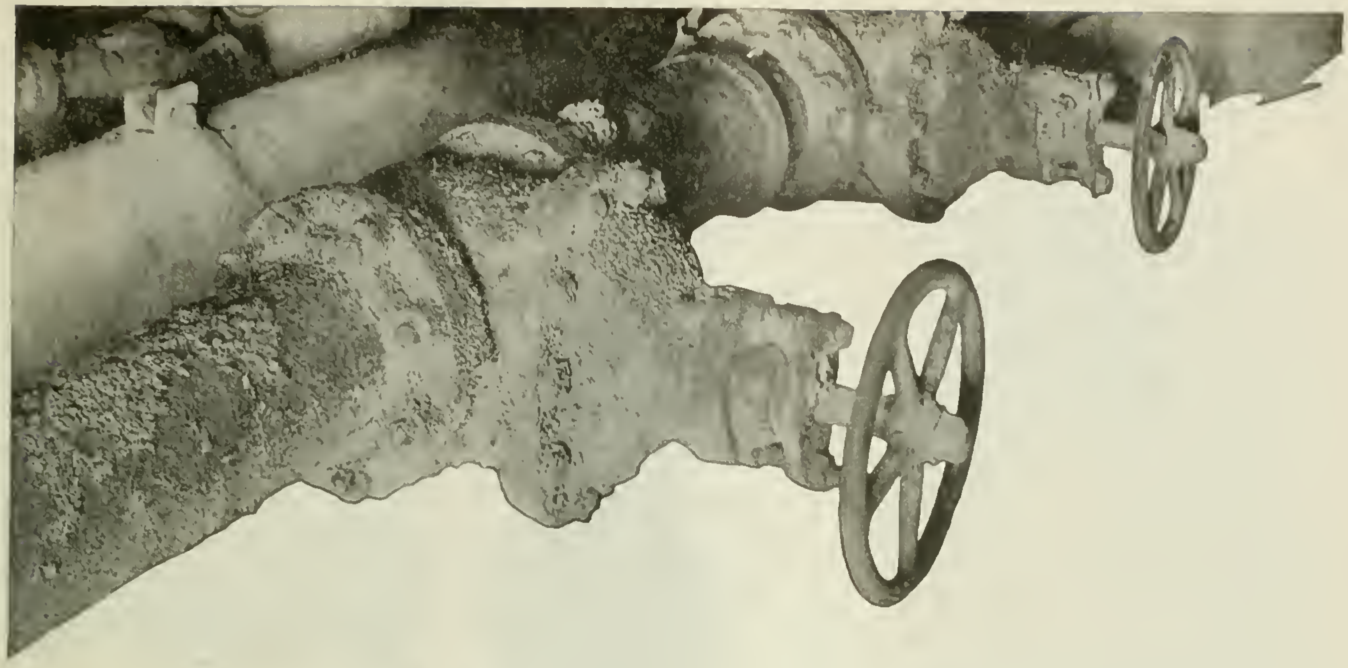


5″ Four Stage Class RDS Pump at Miller Rubber Co.,

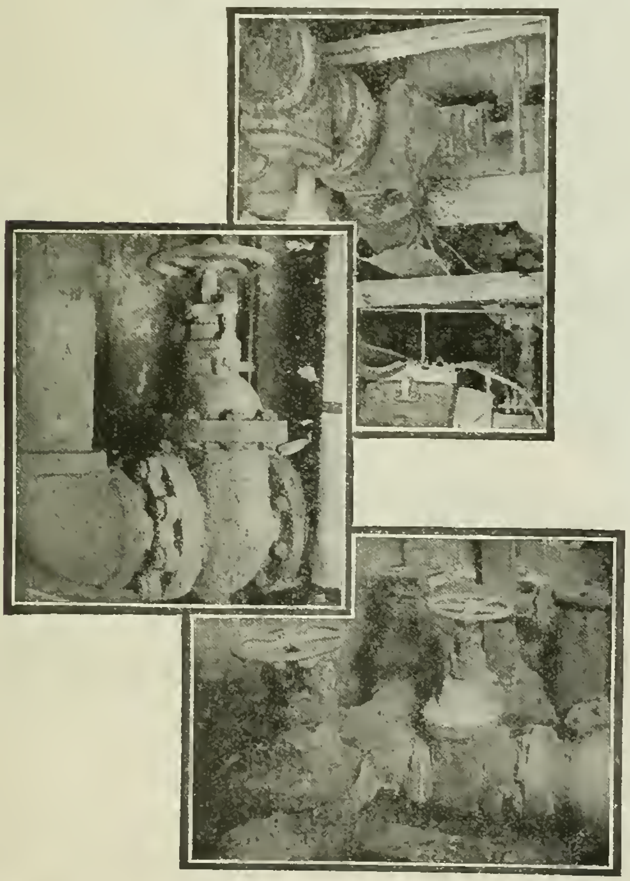
This "Buffalo" Pump handles Boiler Feed Water
500 G. P. M. (810 ft. Head) 1750 r. p. m.

with entire satisfaction and is but one of a complete line made for every industrial requirement. Send for Catalog. #952-A-80

Buffalo Steam Pump Company
148 Mortimer St., Buffalo, N. Y.



Here's *service*—



These Kennedy Veterans are all over 35 years old—and still too good to be replaced.

These Kennedy old-timers show visible evidences of their long-continued operation, but the marks of age are all on the outside. With 35 years of service behind them, each gate still closes tightly in its seat, each stuffing box is still in good working order, and each stem is still perfectly reliable.

The Kennedy Valves of today are *doubly* sure to give similar good service. The conscientious and skillful workmanship that has enabled these veterans to give such long and honorable service are now supplemented by the successive improvements in design and construction resulting from an additional generation valve-building experience.

You are safe in standardizing on Kennedys.

336

Send for the new Kennedy Catalog.

THE KENNEDY VALVE MFG. CO. ELMIRA, N.Y.

BRANCHES: New York, 95 John Street
Boston, 47 India Street
San Francisco, 23-25 Minna Street
Chicago, 228 North Jefferson Street
SALES OFFICES: Salt Lake City, El Paso, Seattle

KENNEDY

Positive assurance of uniform production

Manufactured under the Lunkenheimer Method which involves materials specifications perfected to meet the high standard of Lunkenheimer "Quality" as well as workmanship, inspection and testing specifications of a character which assures the uniform presence in the ultimate assembly of all the elements essential to efficient and economical service results.

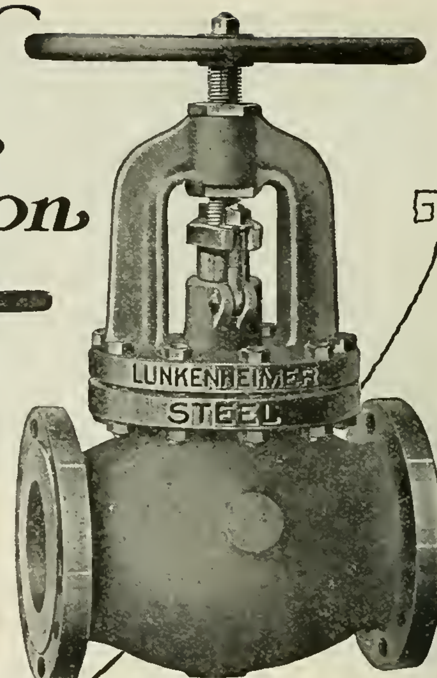


Fig. 606
Globe

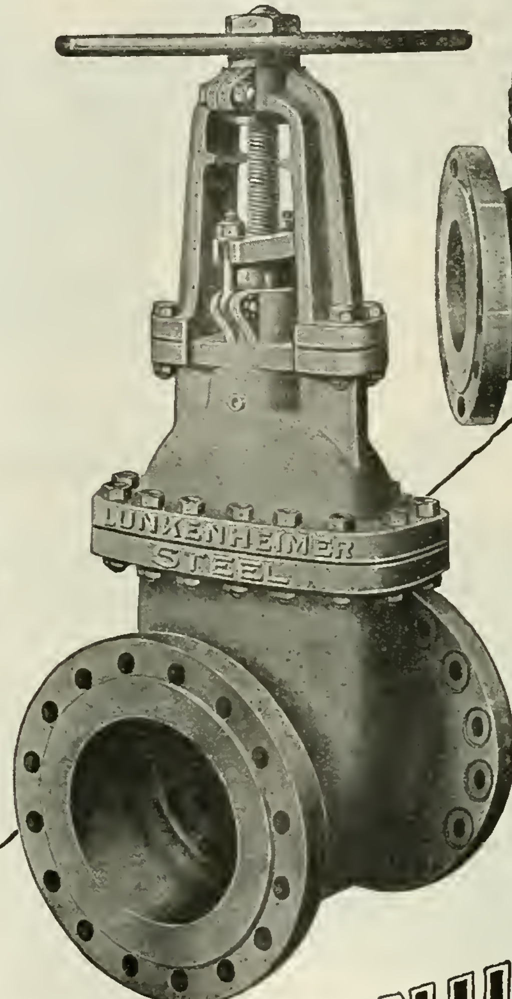


Fig. 1353
Gate

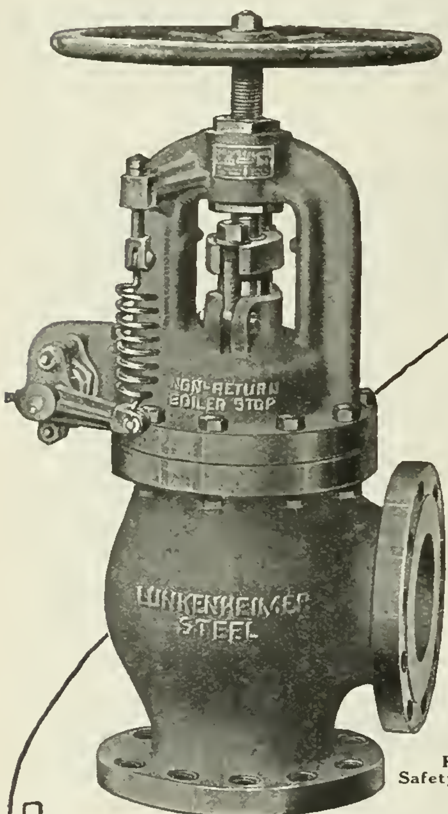


Fig. 1410
Safety Non-return

LUNKENHEIMER STEEL
MONEL MOUNTED VALVES

provide a large factor of safety at their maximum guaranteed working pressure of 350 pounds and 800° F. total temperature.

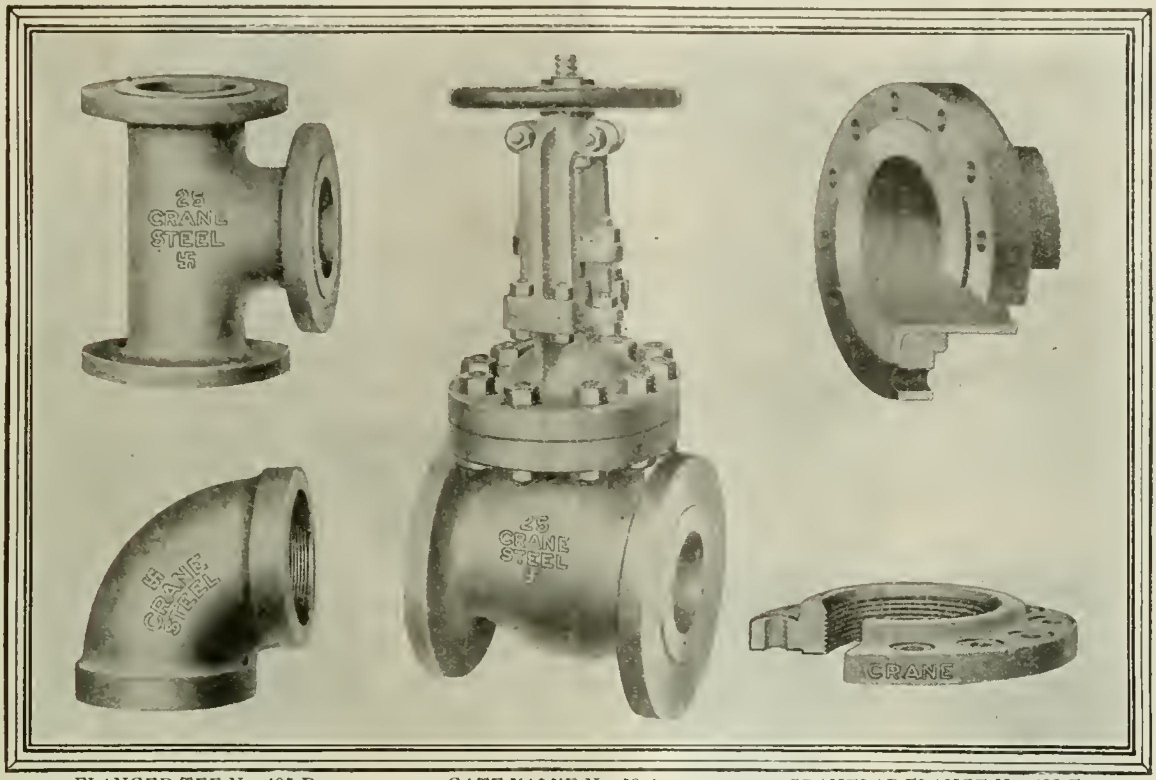
Of correct design, generous proportions, unparalleled materials, exacting workmanship, with renewability of all parts, Lunkenheimer Steel Valves embody that strength and durability so essential to safe and economical continuity of service.

Write for literature

15-19 A-4

THE LUNKENHEIMER CO.
"QUALITY"
LARGEST MANUFACTURERS OF HIGH GRADE ENGINEERING SPECIALTIES IN THE WORLD
NEW YORK CHICAGO **CINCINNATI, U.S.A.** BOSTON LONDON
EXPORT DEPT. 129-135 LAFAYETTE ST., NEW YORK

"America's Best since 1862"



FLANGED TEE No. 405-D
SCREWED ELL No. 760-D

GATE VALVE No. 53-A

CRANELAP FLANGE No. 493-E
SCREWED FLANGE No. 491-E

CRANE "SERIES 25" CAST STEEL MATERIALS

For use in power plants where pressures run as high as 250 pounds and total steam temperatures may reach 750 degrees, Crane has developed a new specialized line of piping materials, designed by engineers of wide experience, known as "Series 25."

Valve bodies, bonnets and discs are cast steel; seat rings, disc rings and stems are monel metal. Fittings are Crane cast steel, accurately machined.

For descriptive literature and specifications of Crane's six new lines of steel valves and fittings, telephone or write the Crane representative at the Crane branch near you.

CRANE

GENERAL OFFICES: CRANE BUILDING, 838 S. MICHIGAN AVE., CHICAGO

Branches and Sales Offices in One Hundred and Forty Cities
National Exhibit Rooms: Chicago, New York, Atlantic City
Works: Chicago, Bridgeport, Birmingham, Chattanooga and Trenton

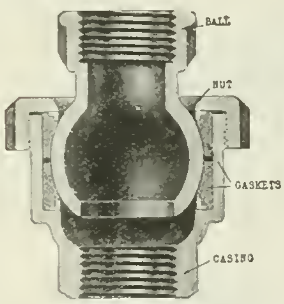
CRANE, LIMITED, MONTREAL. CRANE-BENNETT, Ltd., LONDON
CRANE EXPORT CORPORATION: NEW YORK, SAN FRANCISCO
Cie CRANE, PARIS

Crane "Norfolk" Lavatory

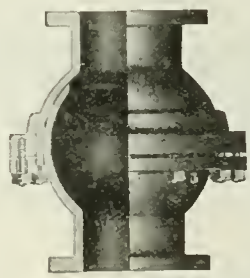
BARCO
Flexible Joints

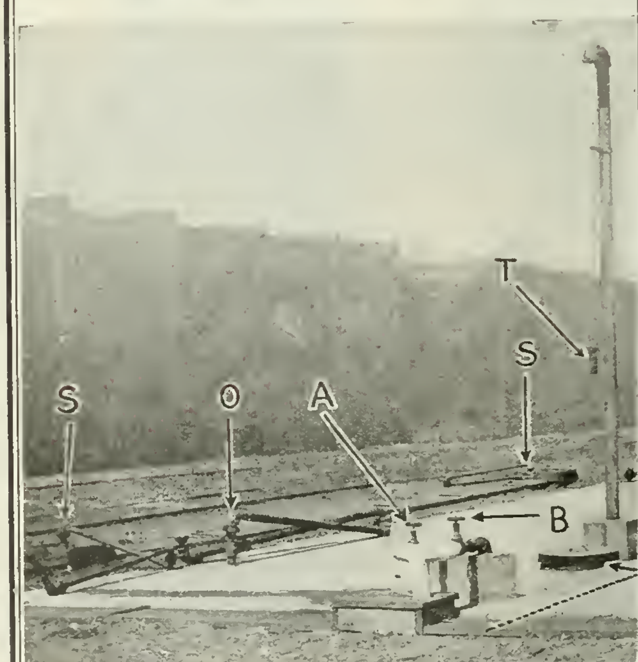
USED AND RECOMMENDED FOR
OIL—STEAM—AIR—WATER, ETC.

Steam Shovels
Mine Pumps
Quarry Pipes
Ore Thawing
Sand Suckers
Dredges
Testing Engines
Testing Boilers
Testing Pumps
Water Works Piping
Water Works Intakes
Loading and Unloading
Docks, Vessels and Wagons
Gas, Plant Lines
Laundry Machinery
Brick Machinery
Rubber Plants
Tire Curing Machines
Platen Presses
Milk and Egg Drying Machinery
Steel Mills and Furnaces
Mud Guns
Oil Lines
Steam and Air Lines
Water Cooling
Hydraulic Lines
Lidgerwoods
City Street Sprinkling Wagons
Bottle Machinery
Sugar Refineries
Oil Refineries
Chemical Plants
Glue Factories
Paper Mills
Box Factories
Roofing Plants
Cinder Ladles
Ship Yards
Moulding Machines
Weed Burners
Expansion Lines
Railroad Shops
Railroad Yards
Railroad Locomotives
Railroad Cars



Screw Ends ¼" to 6"


Flange Ends 4" to 40"



Barco Joints for Unloading Oil from Tank Cars

Will you let us discuss your problems with you? Catalogs on request.

BARCO MANUFACTURING CO.
1801-1815 Winnemac Ave., CHICAGO, ILL.

(See Our Data in 1923-24 A.S.M.E. Condensed Catalogues of Mechanical Equipment)

COPPER EXPANSION JOINTS

For Low Pressure and Vacuum
Made in All Sizes up to 96" Dia. Furnished Standard or with Special Drilling and Face to Face Dimensions if Desired.
Write for Prices
Can Make Prompt Shipments

Hamilton Copper & Brass Works Co., Hamilton, O.

'UNIVERSAL' STAYS TIGHT

CAST IRON PIPE THAT MAKES ITS OWN JOINTS

—no packing, no calking, nothing to deteriorate. Tight—flexible—dependable. Used the country over for water, gas and other service where freedom from leakage is essential.

THE CENTRAL FOUNDRY COMPANY
41 East 42nd Street, New York
Chicago Atlanta Dallas San Francisco

UNIVERSAL CAST IRON PIPE

(See Our Data in 1923-24 A.S.M.E. Condensed Catalogues of Mechanical Equipment)

445

United States Cast Iron Pipe & Foundry Co.
General Office, Burlington, New Jersey

Perfect tightness at every joint

indicates good management and affords real savings!

LEAKS at screw-thread joints are veritable eyesores, and very often give the first impressions that form lasting opinions.

Make criticism from this source impossible and protect your professional reputation by laying up every screw-thread joint with Smooth-On No. 3! This will settle the leak question for good and leave your mind, time and repair money free for bigger things.—Besides, the tightness of your lines, the tidy surroundings, and the *useful* delivery of *all* fluid and pressure will reflect credit upon you.

Insistent and persistent use of Smooth-On No. 3 as your only pipe-joint filler will confirm your judgment in the after years, because Smooth-On No. 3 retains its full metallic iron body, without shriveling or shrinkage. Nothing can dry or blow out.

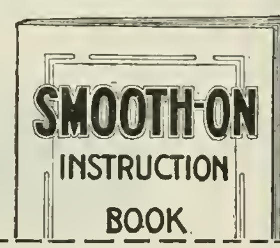
Trying this better method will cost you only two cents for postage if you mail the coupon for free sample, and may save you hundreds of dollars and many wasted hours. Accept this offer and you will learn without expense what hundreds of other engineers have discovered through costly experience.

Get Smooth-On No. 3 all ready to use, in the convenient gray-labeled 1-lb., 5-lb. or 10-lb. tins. At your dealer, or if you will send us his name, we will help him to supply you.

FREE SAMPLE if you mail the coupon

Get this book free!

This 144-page book of simple directions and diagrams will post you well about Smooth-On, where to use each grade, how to apply for best results and what to expect from the finished job, based upon pictures and data from over 100 typical applications.



Smooth-On Manufacturing Co.,
570 Communipaw Ave., Jersey City, N. J.

Please send the free sample can of Smooth-On No. 3 and also copy of the Smooth-On Instruction Book.

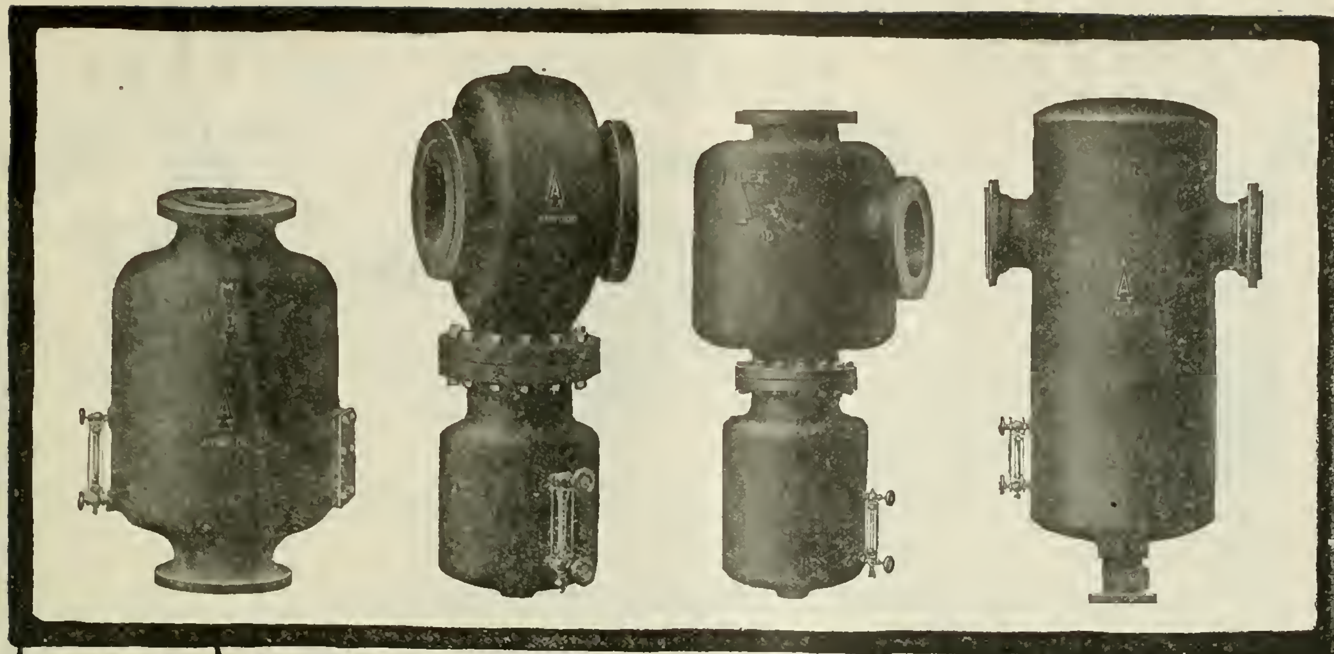
Name...

Address...

....

Mech. Engrg. Dec.

Do it with SMOOTH-ON



"NUGENT" PATENT Automatic and Continuous OIL FILTERING SYSTEMS and OIL FILTERS

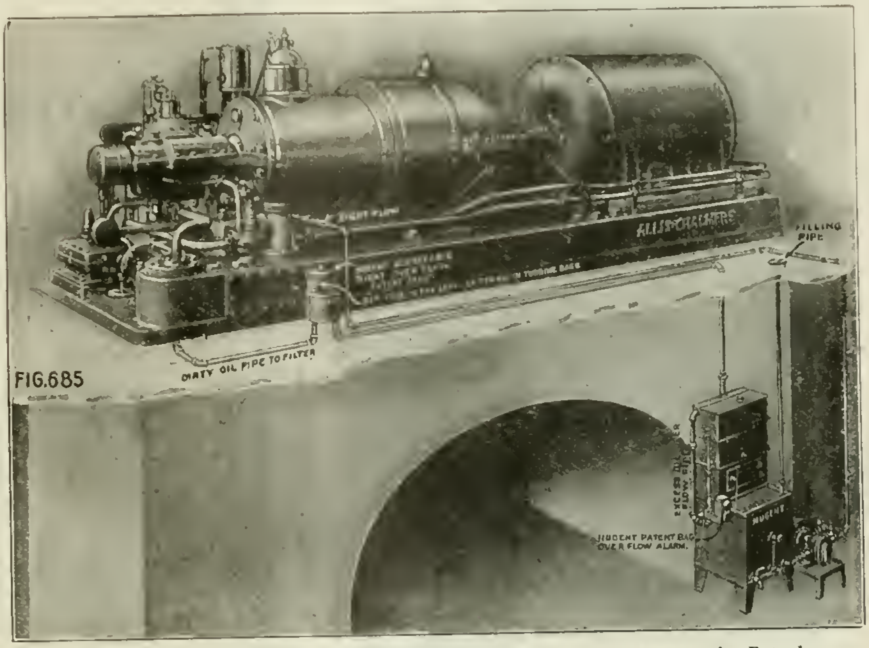
MADE IN CAPACITIES FROM 12 GALLONS PER HOUR UPWARDS.

SPECIAL FEATURES:

(*a*) Two cleansing stages and one precipitating stage for dehydrating
(*b*) Inspection devices at each stage.
(*c*) Patent triple bags for final stage cleansing.
(*d*) Automatic alarm to prevent neglect.
(*e*) Filtering elements removable while running.
(*f*) Water, being a bugbear, is not used as a cleansing medium.
(*g*) Simple, convenient, efficient and safe.
(*h*) Scores in daily operation.

CLEAN OIL ALWAYS ASSURED.

Send for Bulletin P



Nugent Oil Filtering System & Filter on a Steam Turbo Generator at the Petoskey Portland Cement Works, Petoskey, Michigan. (They have three)

WM. W. NUGENT & CO. 410-412 N. Hermitage Ave. Established 1897 **Chicago, U.S.A.**

Manufacturers of Oiling Systems, Oil Filters, Telescopic Oilers, Oiling Devices, etc.

DIXON'S FLAKE GRAPHITE

Engineers who use Dixon's Flake Graphite regularly as a lubricant do not worry about hot boxes or scored cylinders. They know that their machines are giving better and more economical service than if lubricated with oil alone.

Dixon's Flake Graphite reduces the friction in steam cylinders and valves to the minimum, and thus lengthens the life of packing rings, prevents scoring, reduces blowing, eliminates oil from the exhaust, and saves coal.

We will send Booklet No. 100-C upon request.

Joseph Dixon Crucible Co.
Jersey City New Jersey
Established 1827

(*See Our Data* in 1923-24 A.S.M.E. Condensed Catalogues of Mechanical Equipment)

No. 1- Large Flakes
No. 2- Small Flakes

EMPIRE Vertical Dial
Fuel Oil Meter

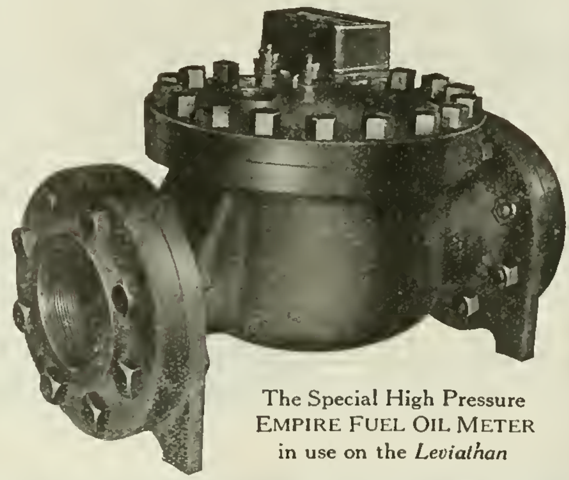
The EMPIRE Oil Meter

IS DIFFERENT

Because it STAYS Accurate

The EMPIRE is an Oscillating Piston meter
It measures by positive displacement
It is extremely accurate
It is remarkably durable
It has been made by us for nearly forty years, in all sizes, from 5/8″ to 6″

Send for Descriptive Circular No. 109



The Special High Pressure
EMPIRE FUEL OIL METER
in use on the *Leviathan*

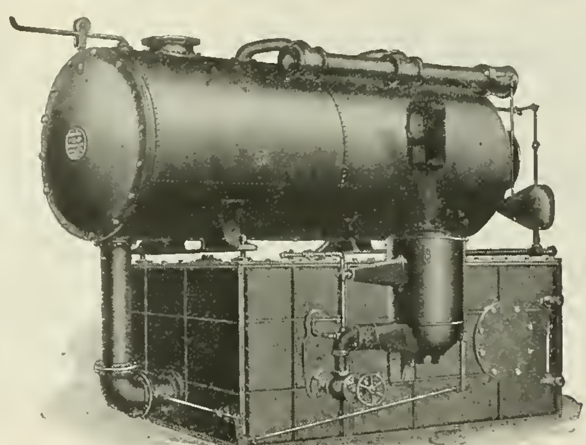
NATIONAL METER COMPANY
299 Broadway, New York

Chicago, Cincinnati, Boston, Atlanta, San Francisco, Los Angeles

HOPPES V-NOTCH METER

—Accurate—

Because it WEIGHS the head



Right there it differs from all other weir Meters that depend upon floats to give precision readings. The height of water behind the V-Notch is weighed in a specially constructed copper vessel suspended from a coil spring which is carefully adjusted and calibrated. The movement of the vessel opposed by the spring is always in exact proportion to the flow through the V-Notch. The recording pen is directly attached to the vessel and moves in true proportion to the flow. By changing the angle of the V-Notch the capacity of the meter may be increased or decreased to suit changed conditions.

Every Hoppes V-Notch Meter is tested in an up-to-date laboratory at all rates of flow and is guaranteed to be accurate to within 1½% at any rate of flow regardless of water temperature.

We also Manufacture Feed Water Heaters, Live Steam Purifiers, Steam Separators, Oil Eliminators and Exhaust Heads.

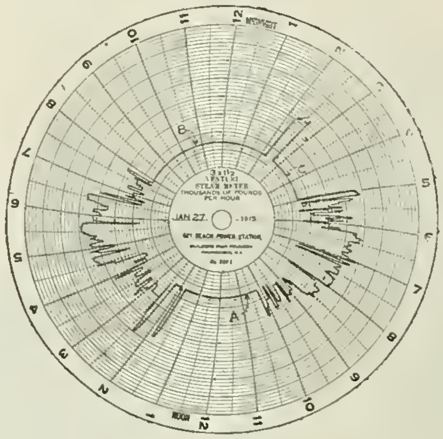
Catalog No. 80 mailed on request

THE HOPPES MFG. COMPANY

47 James St. SPRINGFIELD, OHIO

BUILDERS VENTURI IRON FOUNDRY

Know Where Your Steam Is Going



After producing steam with maximum efficiency, it is of great importance to use this expensive product to the best advantage.

The VENTURI Meter

"Venturi" Registered

The VENTURI Meters located on steam supply lines for prime movers, auxiliaries, heating systems, manufacturing processes, etc., are a constant and accurate check on where and how the steam is used. The Venturi Chart reproduced herewith revealed an unsuspected waste of steam in an electric railway power plant due to faulty operation of an automatic control valve. With Venturi Meters on the job, steam losses and improper distribution of steam output may be promptly corrected.

Shall we send Bulletin 212?

Builders Iron Foundry, Providence, R. I.

NEW YORK KANSAS CITY PORTLAND, ORE. SAN FRANCISCO PHILADELPHIA DALLAS
LOS ANGELES PITTSBURGH TORONTO, CAN. CHICAGO OTTAWA, CAN.

(*See Our Data in* 1923-24 A.S.M.E. Condensed Catalogues of Mechanical Equipment)

TRADE MARK
BRISTOL'S
REG. U. S. PAT. OFFICE.
Recording Pressure Gauges

In the Best Operated Plants

throughout the country provide a certain and continuous check on pressure and on the accuracy of other controlling apparatus. They show the smallest variation from the required standard, and also indicate just when it occurred. A timely aid to ending preventable losses that are ordinarily unnoticed. It pays all the time. Corrective measures taken in time add much to operating economy.

Our 84-page Catalog AR-1006 sent upon receipt of your request.

The Bristol Co.

Waterbury, Conn.

Branch Offices:

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Round Form Model—Recording Pressure Gauge

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for the deposit of your money
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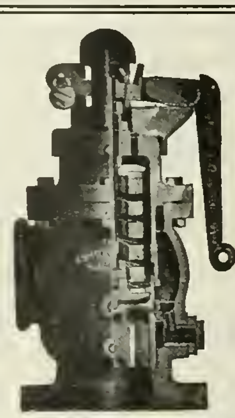
TREASURY SAVINGS CERTIFICATES
for *investment.*



Specify Ashton

Pop Valves and Gages.

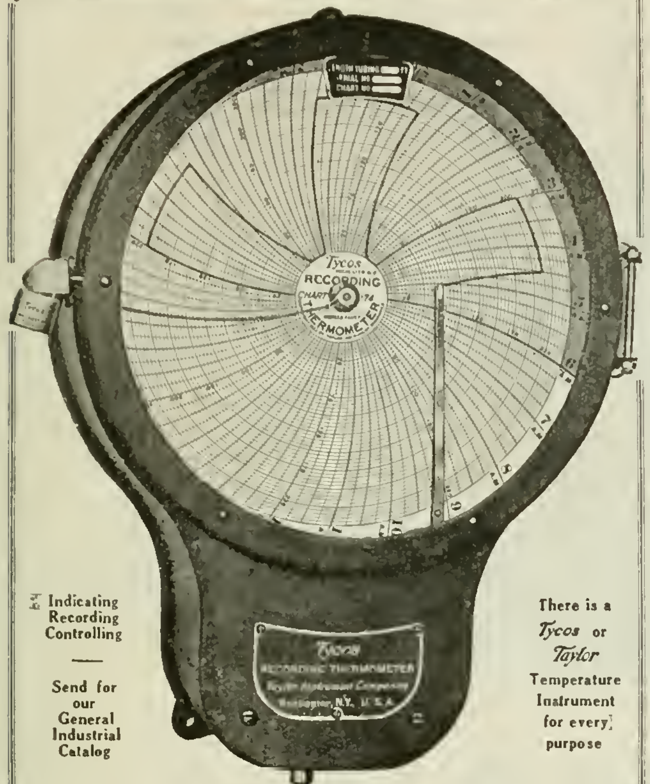
A QUALITY PRODUCT
with a record of over 50 years of dependable service on high-pressure power plant installations.

Send for our Catalogue No. 18

The Ashton Valve Co.
BOSTON NEW YORK CHICAGO
SAN FRANCISCO

1 (*See Our Data in* 1922 A.S.M.E. Condensed Catalogues of Mechanical Equipment)

Tycos — *Tycos*



Indicating
Recording
Controlling

Send for our General Industrial Catalog

There is a *Tycos* or *Taylor* Temperature Instrument for every purpose

Taylor Instrument Companies

ROCHESTER, N. Y., U. S. A.

881

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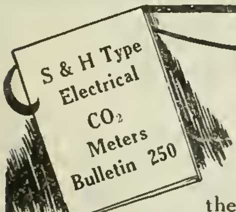
CYCLOMETERS, ODOMETERS, TACHOMETERS
COUNTERS, SPEED COUNTERS FINE DIE CASTINGS,

Hartford, Connecticut



Write!

For Bulletin 250

It gives full details and illustrates the application of Bacharach (S & H Type) Electrical CO_2 Meters, specially designed for practical and efficient operation in boiler-rooms.

Bacharach Industrial Instrument Company
7002 Bennett St., Homewood, Pittsburgh, Pa.

BACHARACH
INDUSTRIAL INSTRUMENTS

W — W

WESTON
Model 310
Single Phase
WATTMETER

ACCURATE

Within 1/4 of 1%

THE unrivalled working standard and precision test instrument.

Made in 3 forms—offering a development in electrodynamometer wattmeters not obtainable in any other similar type of instrument. Its accuracy of 1/4 of 1% is guaranteed on either D.C. or A.C. circuits at any power factor and frequency to 133 cycles per second and any wave form. Doubly shielded—effectually protecting it against stray fields. Stands double its normal load capacity. Has double ranges for both current and voltage circuits. Not affected by any ordinary degree of temperature change. Exceptionally small power consumption. Gives indefinite service. Special instruments available for unusually low factors.

Write for Bulletin 2002 giving complete detailed information

Weston Electrical Instrument Company

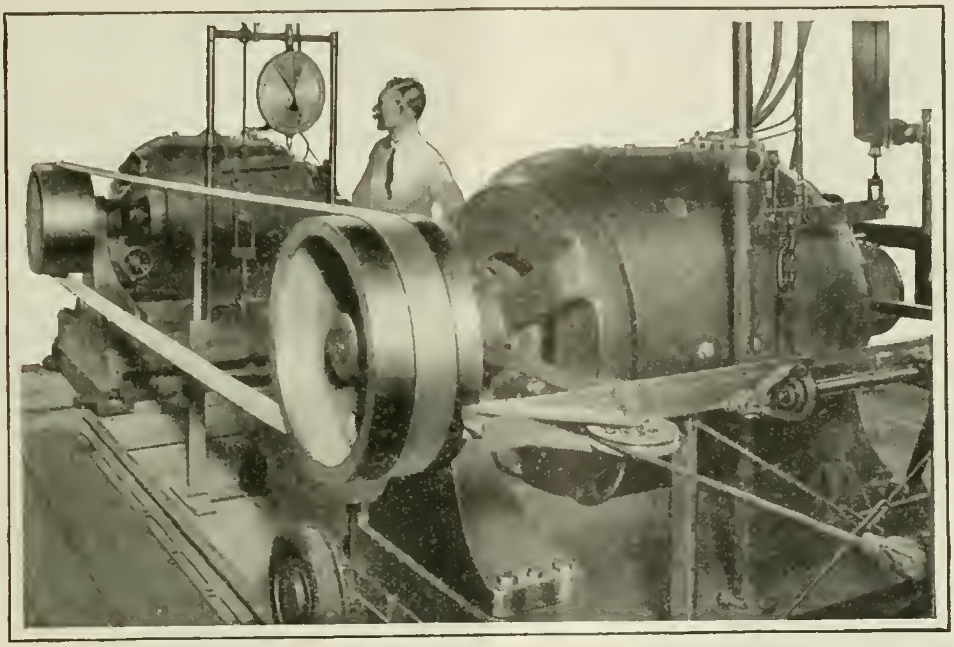
40 Weston Ave., Newark, N. J.

Branch Offices in All Principal Cities

WESTON

Electrical Indicating Instrument Authorities Since 1888

STANDARD - The World Over



Photographed at The Leather Belting Exchange Foundation, Cornell University, where research work on power transmission is being carried on constantly in the interest of industry.

These tests show every plant owner how to save money on belting!

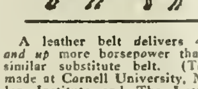
THE photograph above illustrates a test which means a great deal to every buyer of belting. It shows conclusively the comparative efficiency of all types of belts used for transmitting power.

Running under average shop conditions, a 100-H. P. motor drives a 100-H. P. dynamometer. Twenty different types of belts are used, one after the other, to transmit power. These belts are all 4 inches wide and 30 feet long. Each one is put on under the same tension—36 pounds per inch.

A power meter registers the power transmitted by each one. Another meter measures the percentage of "slip," or power lost.

These tests prove, beyond question of doubt, that a good leather belt delivers 40% more power, has a smaller percentage of slip, and a far higher operating efficiency than any other type of belting made.

For instance, assuming the rated capacity of a 4″ leather belt to be 20 H. P., it will deliver 24 H. P., or 4 H. P. more than rated capacity, with only 1½% slip. *The best substitute of equal size usually delivers only 14 H. P. with the same percentage of slip.* On an overload, the leather belt ordinarily delivers 43 H. P. with 2½% slip, while a substitute usually gives only 16 H. P.—*less than the rated capacity of a leather belt of the same size.*



A leather belt delivers *40% and up* more horsepower than a similar substitute belt. (Tests made at Cornell University, Mellon Institute and The Leather Belting Exchange Exhibits.)

These facts hold true with belts of any width or length—with any pulley ratio—and under any shop conditions. (Except that leather shows to even better advantage in most cases.)

Leather is not only more efficient—it is far more durable; has a high salvage value; can be made positively water-proof—and is, therefore, the most economical, dependable material on earth for transmitting power!

The results of these tests, together with other interesting information on power transmission, are combined in six valuable booklets. These will be sent you free upon request. They tell you how to choose the right kind of belting and how to care for it *to save money.* Simply sign and mail the coupon.

You are also invited to write us regarding power transmission problems. These, whenever possible, will be answered free of charge.

An Interesting Exhibit

The test illustrated above, with 10-H. P. machines and two-inch belts of all kinds, forms a part of The Leather Belting Exchange's exhibit at the

SECOND NATIONAL EXPOSITION OF POWER AND MECHANICAL ENGINEERING

Grand Central Palace
New York City, N. Y.
December 3rd to December 8th

Address—Research Division

THE LEATHER BELTING EXCHANGE, Forrest Building, Philadelphia

The Leather Belting Exchange is not a company operating for a profit or for selling belts. It was organized by the leading leather belting manufacturers of America in the desire to furnish impartial information on leather belting to manufacturers, engineers, and technical schools. It maintains a competent staff of experts in Philadelphia and at Cornell University who will gladly answer questions on power transmission without cost or obligation. In the broader interest of leather, it is affiliated with the leading Sole and Belting Leather Tanners in their nation-wide campaign on leather and the tanning industry. For information regarding leather, itself, address

AMERICAN SOLE *and* BELTING LEATHER TANNERS, 17 Battery Place, New York

Nothing takes the place of Leather

THE LEATHER BELTING EXCHANGE,
Forrest Building,
Philadelphia.

Please send me your six booklets on power transmission—FREE. Also, without obligation, place me on your mailing list for subsequent information developed by your research work on belting.

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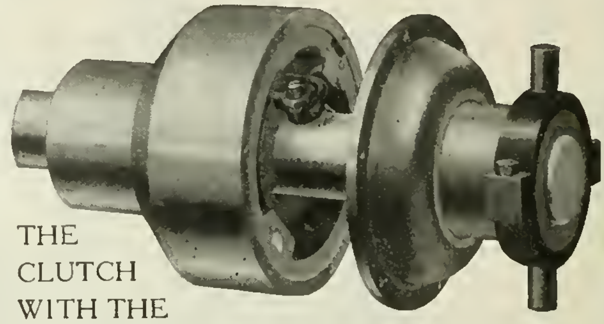
GROUND SHAFTS

for line shafting, lead screws, counter shafts, piston rods, arbors and all similar equipment. Ultimate strength about 80,000 lbs.; elastic limit about 42,000 lbs. Slightly higher in price, but economical because of saving in assembly cost and long service.

We can also furnish Ground Alloy Steel Shafts ultimate strength up to about 140,000 to 150,000 lbs.; elastic limit about 130,000 lbs. to 140,000 lbs.

CUMBERLAND STEEL CO.
CUMBERLAND, MD.

THE CLEVELAND FRICTION CLUTCH



THE CLUTCH WITH THE VELVET PICK-UP

It's the easy pick-up that prolongs the life of the CLEVELAND and the machine it operates. It releases instantly. Fully enclosed and running in oil. Made in clutches and cut-off couplings in sizes ¾ H. P. up.

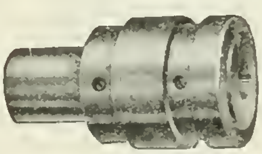
Ask for Bulletin 100

WESTERN ENGINEERING & MFG. CO.
362 EAST GRAND AVENUE
CHICAGO, ILL.

(See Our Data in 1923-24 A.S.M.E. Condensed Catalogues of Mechanical Equipment)

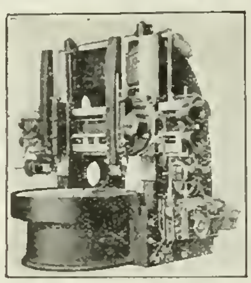
THE JOHNSON FRICTION CLUTCH

AS USED ON THE "NEW" TYPE COLBURN HEAVY DUTY VERTICAL BORING MILLS



SIX JOHNSON FRICTION CLUTCHES ON EACH

Single Clutch, Exterior



Courtesy Colburn Mach. Tool Co., Cleveland, Ohio.

Here is Proof of the Value of Johnson Clutches on Machinery.

Let us tell you about its application to your machine.

Write for Catalog "C"

THE CARLYLE JOHNSON MACHINE CO. MANCHESTER, CONN.

SPECIALIZED CONSULTING SERVICE

in ALL BRANCHES of the ENGINEERING FIELD

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Accounting	Industrial Plants	Production
Appraising	Inspection	Refrigeration
Combustion	Machinery Designing	Research
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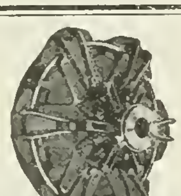
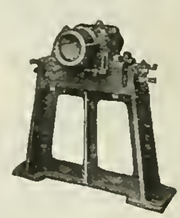


THE FALLS CLUTCH & MACHINERY CO.



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POWER TRANSMISSION APPLIANCES

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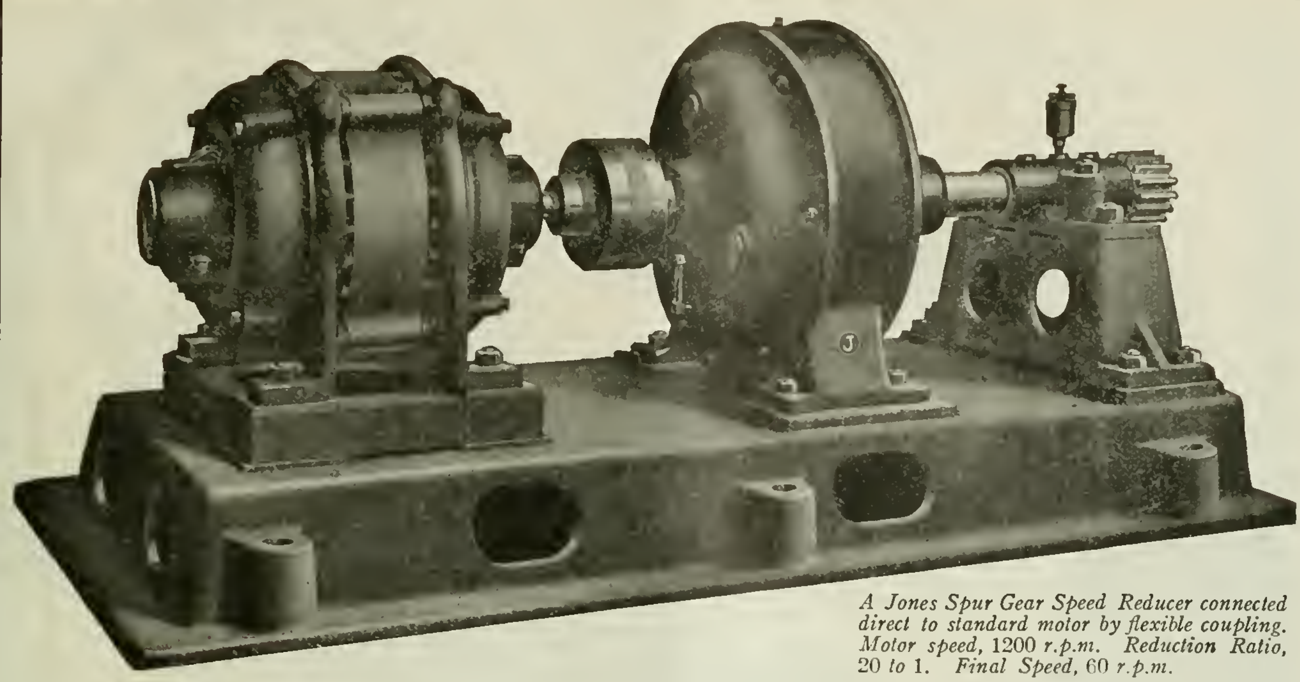
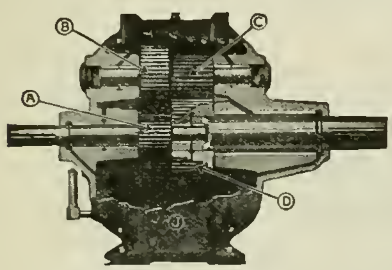


A Jones Spur Gear Speed Reducer connected direct to standard motor by flexible coupling. Motor speed, 1200 r.p.m. Reduction Ratio, 20 to 1. Final Speed, 60 r.p.m.

The Jones Spur Gear Speed Reducer Effects Economy in Driving Machinery



A—Pinion meshes with and drives three gears, B.

B—Gears are mounted integral with three pinions, C.

C—Pinions mesh with and drive slow speed gear, D.

Let us assume that a standard motor is purchased to drive a machine at a given speed.

To reduce the speed of the motor to the speed of the machine, *speed reduction appliances* are also required. These often consist of belts, chains, shafts, pulleys, or gears. They represent a perishable outlay, demanding frequent attention, each unit of which (the pulley, shaft, belt, etc.) is independent of the other.

Why not install one—*complete reduction unit*, mounted on the same base as the motor, which will reduce speeds in ratios as high as 200 to 1, and which demands no attention other than an occasional oiling?

W. A. Jones Foundry & Machine Company
Main Office and Factories:
4400 West Roosevelt Road, Chicago

Branch Sales and Engineering Offices:

NEW YORK	MILWAUKEE	BUFFALO	PITTSBURGH
26 Murray Street	1st Wis. Nat'l Bank Bldg.	184 Main St.	Union Arcade

Cast-Iron Pulleys
Cut and Cast Gears
Speed Reducers

Enclosed Worm Gear Drives
Hangers—Boxes—Couplings
Friction Clutches

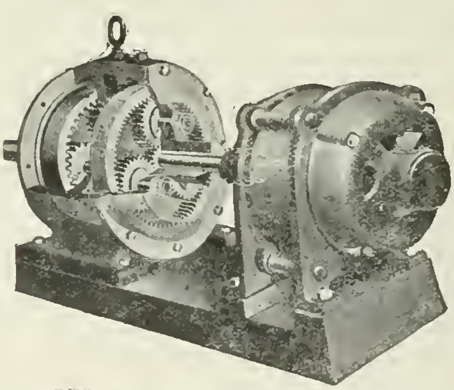
Jones

MEMBER OF AGMA

Spur Gear SPEED REDUCERS

FOOTE SPEED REDUCER TRANSMITTING POWER FROM MOTOR TO HEAD DRIVE AT ATLANTIC ELEVATOR, CHICAGO

Foremost Engineers Approve
FOOTE SPEED REDUCER
Engineering & Construction



When the engineers of such companies as Ford Motor Co., Snoqualmie Falls Lumber Co., Indiana Portland Cement, Atlantic Elevator, Republic Chemical Co., Durant Motors, and innumerable others equally well known choose FOOTE SPEED REDUCERS it is a high recommendation. It assures you that when you make FOOTE SPEED REDUCERS your choice for reducing the speed of your motors and transmitting the power to your conveyors, mixers, agitators, etc., you are choosing wisely.

FOOTE SPEED REDUCERS replace belting, chains, open gearing—creating greater production efficiency and worth while economy.

MEMBER OF AGMA

FOOTE ENGINEERING SERVICE

Perhaps your plant can be put on a basis of greater efficiency and better economy. Our engineers will be pleased to determine whether this can be done—without obligation to you. Write us now.

FOOTE BROS. MACHINE GEAR & CO.

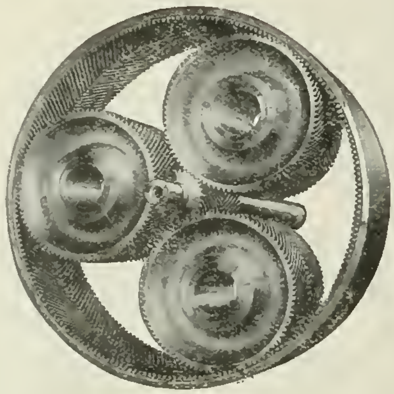
248-258 N. Curtis St. | *Mfrs. of bakelite micarta pinions and cut gears of all kinds. Send for catalogue.* | Chicago, Ill.

J. R. SHAYS, JR.
100 Greenwich St.
New York City

KING & KNIGHT
Underwood Bldg.
San Francisco, Cal.

See Our Data in 1923-24 A.S.M.E. Condensed Catalogues of Mechanical Equipment

The Turbo Gear Will End Your Transmission Problem



Beyond doubt it is the ideal reduction gear for increasing or reducing the speed of your fan, pump, turbine, compressor or other equipment. Maintains axial alignment and insures perfect balance. Entirely self contained and very compact. Forced lubrication minimizes friction and wear. Cool and quiet operation assured.

Furnished in ratios from 3:1 to 15:1 any capacity up to 1500 HP depending on speeds.

Send for your copy of our bulletin No. 103 which fully describes the Turbo Gear and its application.

Write for our recommendations to suit your requirements.

Poole Engineering & Machine Company

Manufacturers of Power Transmission Machinery Since 1843

Main Offices & Works BALTIMORE, MD., U. S. A.

See Our Data in 1923-24 A.S.M.E. Condensed Catalogues of Mechanical Equipment

MEDART

Gearing

Spur, Bevel, Mitre, Internal, Worm, Mortise—all styles. Wood Cogs.

Medart Gears are made in every type—of any material—either pattern-molded, machine-molded or cut. Gears **cut up to 72 inches diameter.**

Medart patterns are unusually complete—prices attractive—service prompt. Send for our new Catalog No. 43 or submit your specifications for our engineers' estimate.

The Medart Company

(Formerly Medart Patent Pulley Co.)

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More extended information on various Medart products is contained on page 251 of the 1923-24 A.S.M.E. CONDENSED CATALOGUES.

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ENCLOSED GEAR DRIVES
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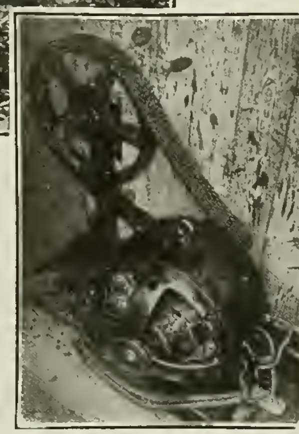
CUT SPUR = CUT BEVEL = CUT WORM = GEARING

FAWCUS MACHINE CO. Pittsburgh, Pa.

See Our Data in 1923-24 A.S.M.E. Condensed Catalogues of Mechanical Equipment

A NEW MEANS OF RAPID TRANSIT

This Moving Walk is designed to replace subway "shuttle" trains and similar short run equipment in underground city traffic. There are three narrow platforms running at three, six and nine miles an hour arranged in a continuous loop that affords transit in either direction. A continuous walk inside the low speed platform permits access at any point.



This plant is now in operation at Jersey City and is driven by an electric motor through a

"WHITNEY"
LONG SERVICE CHAIN
SILENT TYPE

as shown by the small illustration at the right. In a drive of this kind it is imperative to secure long life combined with a certainty of continuous operation day in and day out with no likelihood of skipping the sprocket teeth. Therefore, the "WHITNEY" Long Service Chain was selected.

The Engineering Department of the Whitney Mfg. Co. is always at your disposal to consider and make suggestions on any possible application of chain drives.

The Whitney Mfg Co., Hartford, Conn.

CHAINS — KEYS AND CUTTERS — HAND MILLING MACHINES

NEW YORK	BOSTON	PHILADELPHIA	SAN FRANCISCO	SEATTLE
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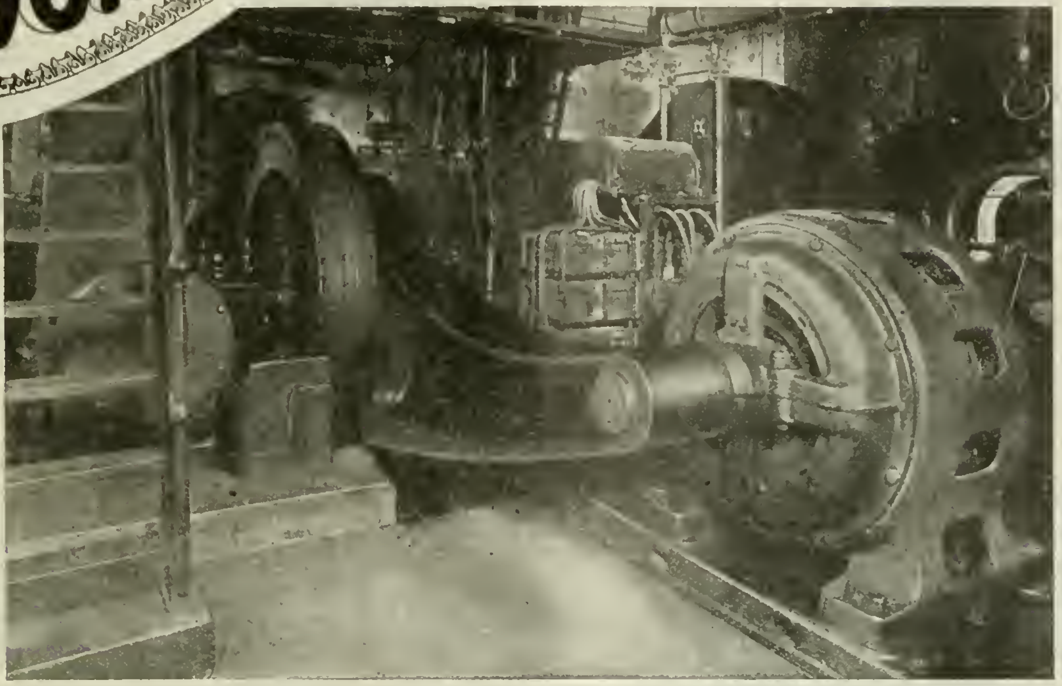
(See Our Data in 1923-24 A.S.M.E. Condensed Catalogues of Mechanical Equipment)

MORSE SILENT CHAIN DRIVES



Morse Silent Chain Drive in action, at the Greenwald Packing Corporation plant, Baltimore, Md. Driving from motor to 90 ton refrigerating machine. Motor speed 480 R.P.M. Machine speed 108 R.P.M. Motor H.P. 150. Width of chain 13 in. Center distance 10 ft.

To Get Efficiency

"To get efficiency"—is the terse reason why Morse Silent Chain Drives were selected, says Mr. C. Heron, C. E. of The Greenwald Packing Corporation, Baltimore, Md.

Mr. Heron is in a position to know, for in addition to this drive, there are four other Morse Silent Chains on elevator drives, installed in 1906 and "still going good."

* * * * * *

Efficiency is always a factor. Efficiency in transmitting power. Efficiency in requiring practically little attention. Efficiency in terms of long useful, year after year, trouble-free service.

Morse Silent Chain Drives transmit 98.6% of the developed power. Sustain this very high rate throughout the life of the Drive. In addition, provide positive speed ratio between driver and driven; save valuable space by using short centers. Run quiet, cool and clean. Have long life with low upkeep and maintenance costs.

"To get efficiency," capable transmission engineers will gladly assist you.

MORSE CHAIN CO., ITHACA, N. Y.

There is a Morse Engineer near you

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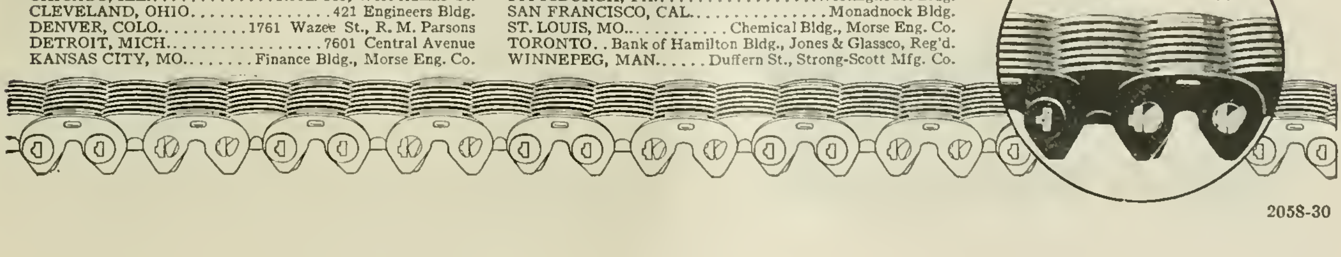

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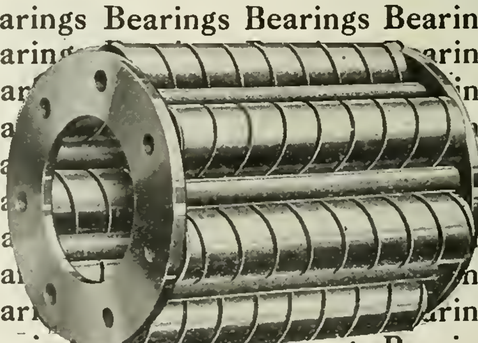

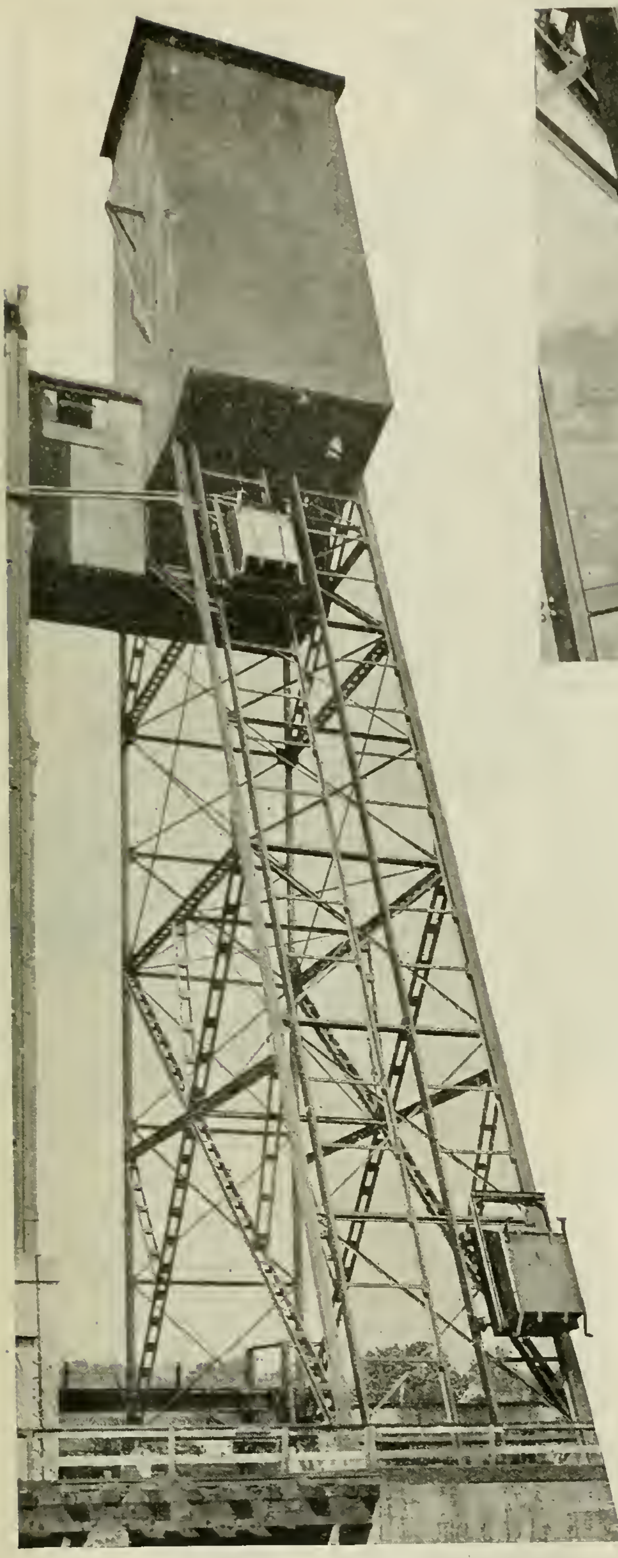

The Skip Hoist
For Handling Coal

HERE is an effective coal handling equipment—a Link-Belt Skip Hoist. It is used by the American Construction & Securities Co., Williamsport, Md., to take coal to the horizontal conveyors which deliver to the coal bunkers.

The Link-Belt Skip Hoist represents more than twenty years experience in building this type of equipment.

Like some other types of material-handling machinery, it is better suited to certain conditions than elevators and conveyors of the chain-and-bucket type.

We build, in their entirety, at our own plants, all the approved types of conveying equipment. Our plans therefore are made without prejudice and include the Peck carrier, belt conveyors, bucket elevators and conveyors, coal crushers, power hoes, locomotive and crawler cranes, bins, chutes and all equipment for handling coal and ashes.

Let our experienced engineers show you how you can save time, labor and money by handling your coal with modern Link-Belt machinery.

1402

LINK-BELT COMPANY

PHILADELPHIA, 2045 Hunting Park Ave. **CHICAGO, 300 W. Pershing Road** **INDIANAPOLIS, 202 S. Belmont Ave.**

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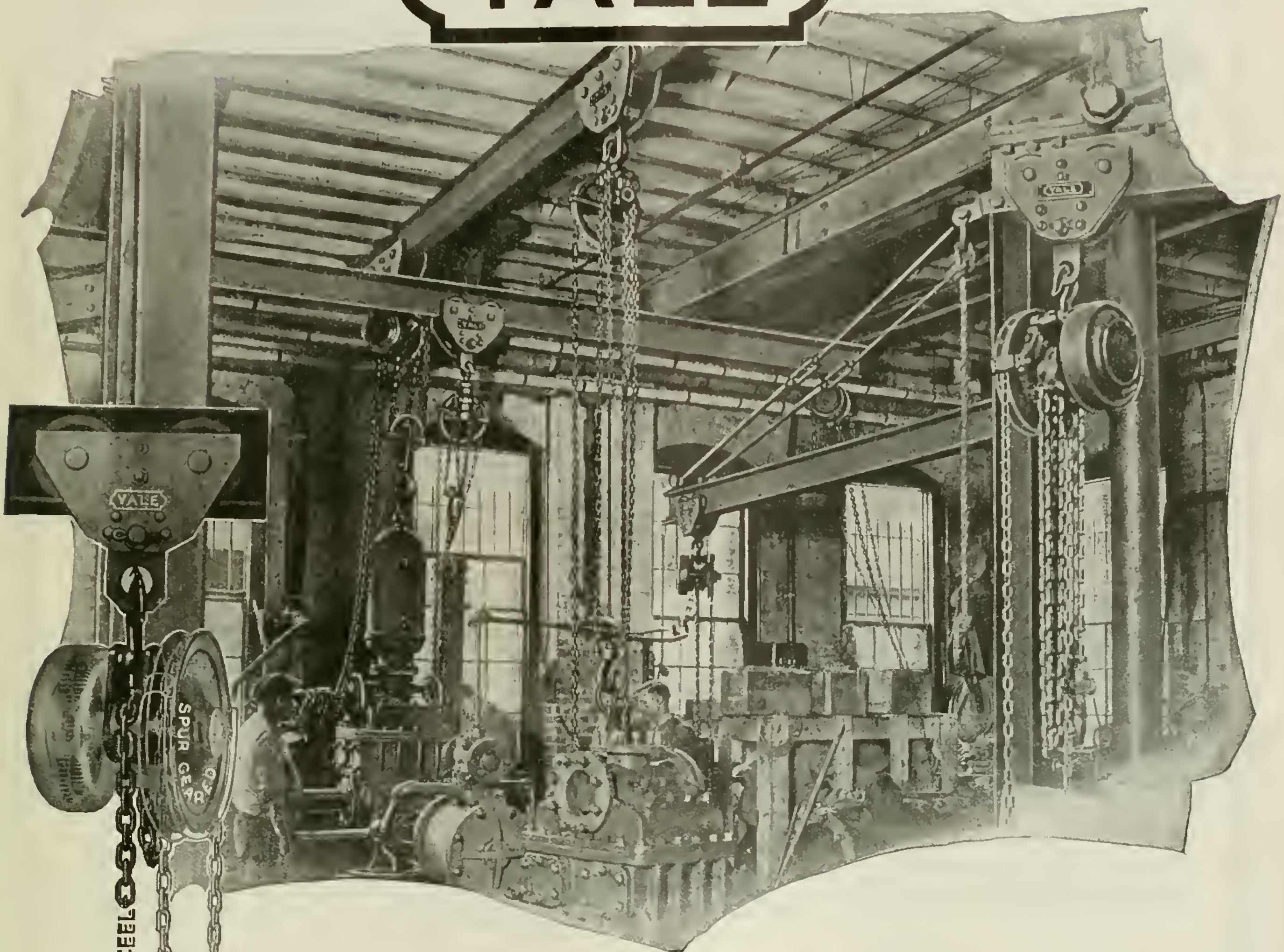
Pittsburgh	335 Fifth Ave.	Huntington, W. Va.	Robson-Prichard Bldg.	Denver	520 Boston Bldg.	Birmingham, Ala.	720 Brown-Marx Bldg.
St. Louis	1016 Central Nat'l Bank Bldg.	Cleveland	329 Rockefeller Bldg.	Atlanta	24 Marietta St.	Link-Belt Limited	Toronto and Montreal

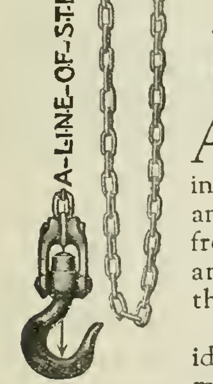
H. W. CALDWELL & SON CO.:—Chicago, 17th St. and Western Ave. New York, 2676 Woolworth Bldg. Dallas, Texas, 709 Main St.

LINK-BELT MEESE & GOTTFRIED CO.:—Los Angeles, 400 E. Third St. San Francisco, 19th and Harrison Sts. Seattle, 820 First Ave. S. Portland, Ore., 67 Front St.

LINK-BELT

TRADE **YALE** MARK





Every Chain Block is a YALE

AT the plant, illustrated above, of a leading pump manufacturing company located in Brooklyn, New York, Yale Spur-Geared and Screw-Geared Chain Blocks suspended from I-beam trolleys are used for all lifting and transporting of heavy machinery throughout the works.

The management considers the system an ideal and highly efficient means of handling materials and has for many years specified Yale Chain Blocks exclusively.

Of the utmost importance in this, as in all other installations, is the question of safety.

Yale Chain Blocks, "from hook to hook a line of steel," have unquestioned strength in each component part. Their use eliminates any chance of failure. The load hook designed to open up gradually under an excessive overload, is the "safety-valve" that prevents accidents through an operator's negligence.

Yale Chain Blocks, requiring for their best work only periodical oiling, perform the same highly efficient service year after year.

Service considered, Yale equipment is decidedly a good investment.

YALE

Chain Blocks, Electric Hoists } For Lifts

I-Beam Trolleys, Industrial Trucks } For Shifts

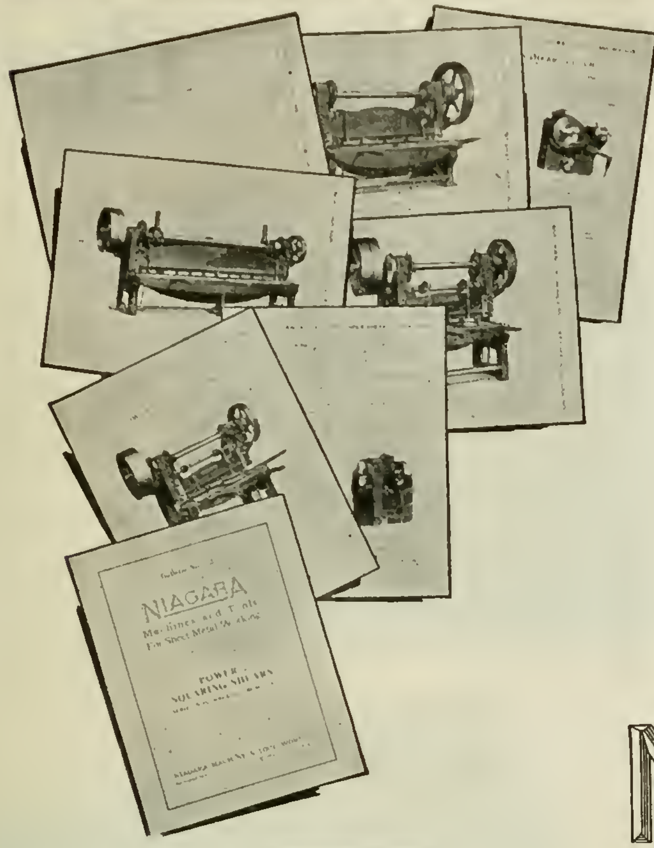
The Yale & Towne Manufacturing Co.

Makers of Yale Products: Locks, Door Closers and Material Handling Equipment

Stamford, Conn., U. S. A.

Yale Made is Yale Marked

YALE Hoisting and Conveying Systems



New Bulletin

On Our Medium Size
Power Squaring Shears

Is Now Ready

Bulletin No. 72 covering Niagara Power Squaring Shears for capacities, ¼″ soft steel and lighter, is now off the press. This 40-page book illustrates and describes our medium size shears and gives tables of sizes, capacities and special features. Ask for a copy.

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Established 1879
BUFFALO, N. Y. U. S. A.

NIAGARA

(See Our Data in 1923-24 A.S.M.E. Condensed Catalogues of Mechanical Equipment)

The Engineering Societies Library

ONE of the largest collections of engineering literature in the world is that found in the Engineering Societies Library, 29 West 39th Street, New York.

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The library is open from 9 a.m. to 10 p.m., with trained librarians in constant attendance. Its resources are at the service of the engineering and scientific public.

POWER PUNCHING & SHEARING MACHINERY

Helve and Drop Hammers

Spacing Tables

THE LONG & ALLSTATTER CO.
HAMILTON, OHIO

(See Our Data in 1923-24 A.S.M.E. Condensed Catalogues of Mechanical Equipment)

ROLLING MILLS of ALL KINDS and TYPES

"ADAMITE" **ROLLS** "MANGANITE"

CHILLED, SAND and STEEL

STEEL AND IRON CASTINGS UP TO 75 TONS
BRASS CASTINGS
"ADAMITE" AND SPECIAL STEEL CASTINGS

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CAST AND CUT TEETH GEARS AND PINIONS
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ANNEALING BOXES AND BOTTOMS

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Pittsburgh, Pa.

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FORT PITT FOUNDRY
A. GARRISON FOUNDRY

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Its practicability dem

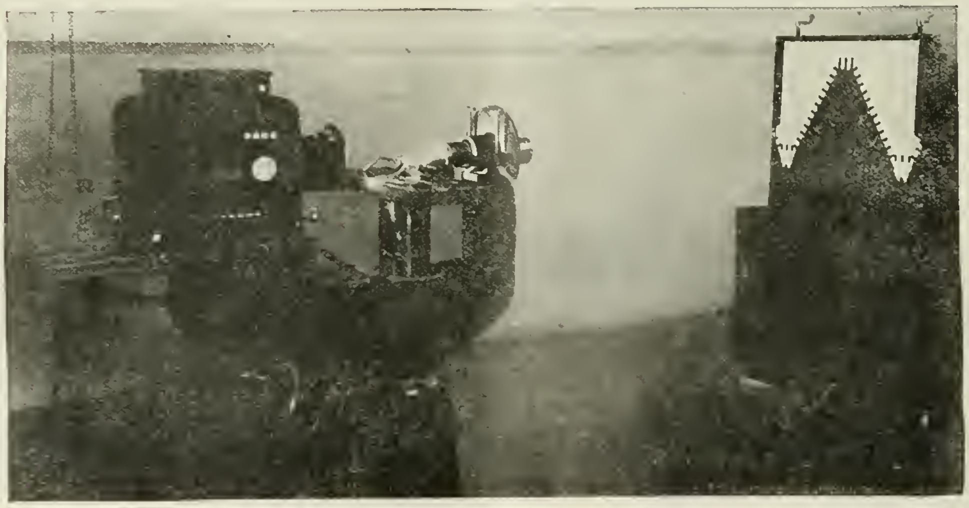
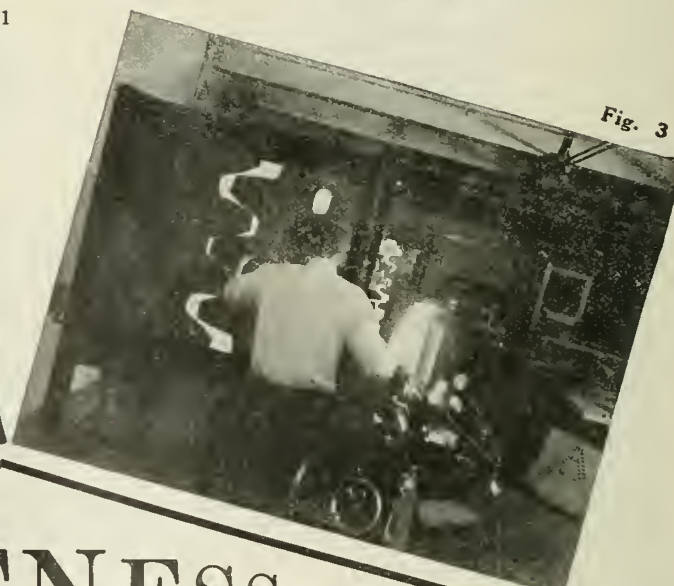


Fig. 1

Fig. 2

Fig. 3



HARTNESS

Fig. 4

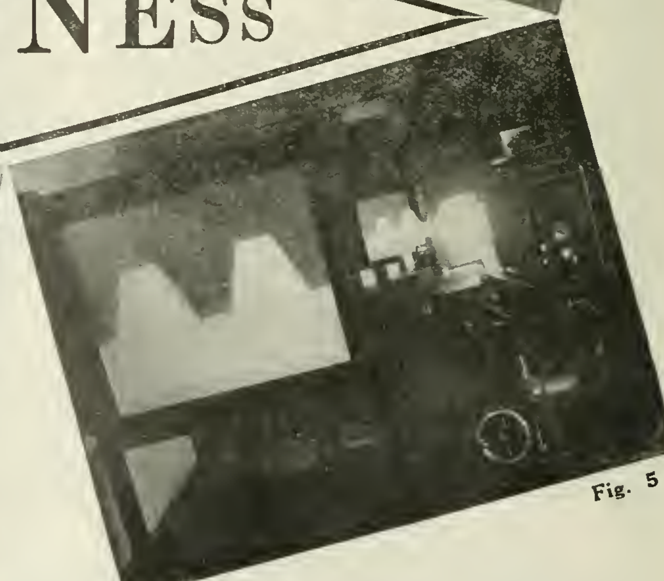


Fig. 5

A Thoroughly Equipped Shop *for All Kinds of* MACHINE WORK

RECENT enlargement of our facilities enables us to offer exceptionally favorable terms and deliveries for any kind of machine shop work on a manufacturing basis.

WE now have 40,000 sq. ft. of floor space thoroughly equipped with modern machine tools, together with pattern shops, drafting rooms, etc., and backed up by an executive staff with nearly fifty years' successful experience in manufacturing a widely diversified line of mechanical products.

OUR experience and equipment is especially favorably for the manufacture of compressors, steam engines, pumps, etc. The wide range of our past activities includes the manufacture of special machinery for many prominent concerns.

Correspondence is cordially invited and will receive personal attention from the head of our company.

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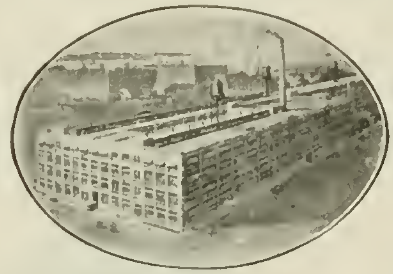

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A Precision Measuring Instrument

Scientifically correct in its readings, it is yet commercially adaptable to the usual shop processes. It thus brings to the measurement of ordinary bench and machine work the precision hitherto not to be had even by elaborate and costly methods. Once set to a standard, it eliminates the personal error and permits precision measurements, to 1/10,000 of an inch, to be made with great rapidity. Its advantages in quantity production make it essential where the highest quality and lowest cost must be combined. Let us send you the circular.

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BALL, ROLLER AND THRUST BEARINGS

LOOK FOR THE ALLEN PROCESS SOCKETS CORNER TRIANGLES
TRADE MARK

This mark tells what to look for in a hollow screw—assuming you're looking for 30% *more strength* than in broached screws.

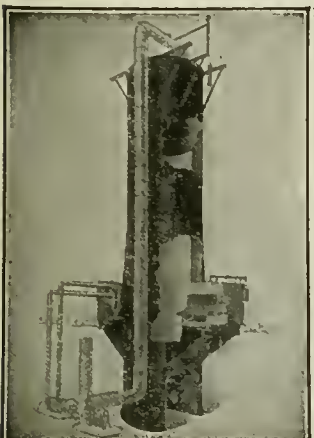
Examine the bottom of the socket-hole: In the corners are little triangular "pits," stamped by the hexagon punch in the Allen process of cold-drawing.

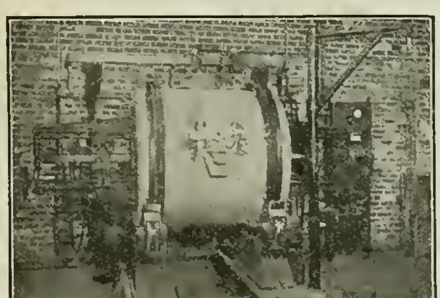
These corner triangles *identify* your cold-drawn "ALLENS." They guide you in getting *"the goods"*---and the Allen booklet will further guide you. Request it!

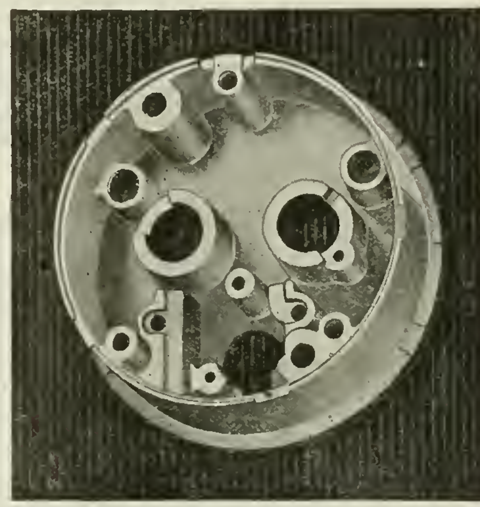
THE ALLEN MFG. CO.

131 Sheldon St., Hartford, Conn.

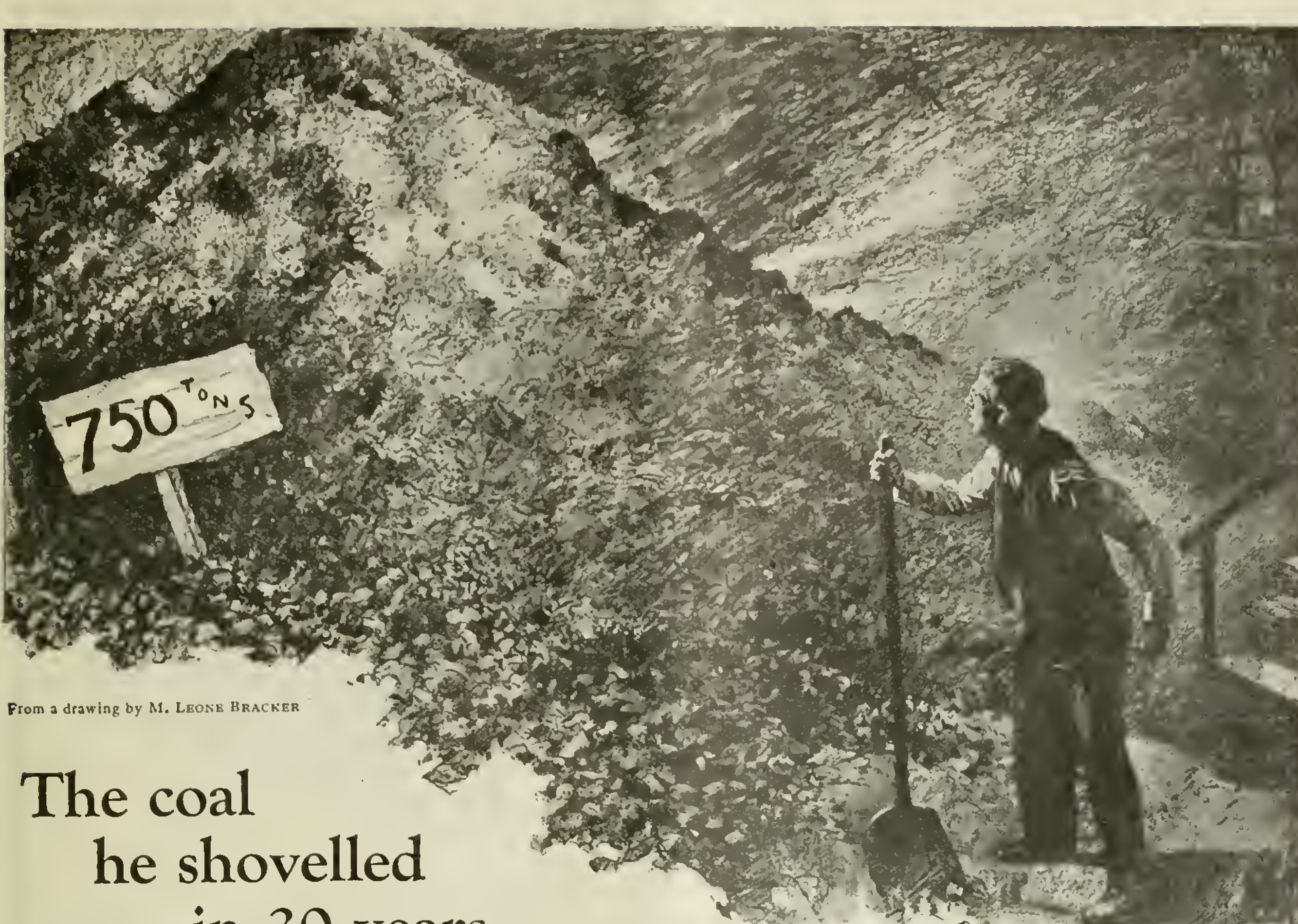
LOOK FOR THE ALLEN PROCESS SOCKETS CORNER TRIANGLES
TRADE MARK







Doehler Die-Cast Zinc Alloy Ignition Housing



From a drawing by M. Leone Bracker

The coal he shovelled in 30 years

© ARCO 1923

—*a true story for Architects and Heating Engineers*

LET US tell you the story of a home-owner in Evanston, Illinois.

He has had an Ideal Boiler in his cellar for thirty years; it cost him new, about $275 (without radiators and piping).

His house is large. In these thirty years he has shovelled more than 750 tons of coal which, at an average cost of $10 a ton, amounts to $7,500 or 27 times the original cost of the boiler itself!

Three things can be learned from this story:

1 How amazingly Ideal Boilers last. In thirty years there have been no repairs except a new grate, the old one having been "burned out through carelessness."

2 How little any boiler costs in comparison with the cost of the coal it burns. Since the difference in the first cost is so small, it is wisdom to urge clients to buy the best.

3 There have been many improvements in Ideal Boilers, just as there have been improvements in automobiles. It would pay any home-owner to take out his old heating apparatus and install a modern Ideal Boiler. It would cut his annual coal bill one-third, which would quickly pay for the new boiler.

We wonder how many home-owners actually realize how trifling is the first cost of their heating plant compared with the coal they burn! We are stressing this thought to millions of home-owners through the national magazines. Isn't it pretty sound logic to preach to your clients?

AMERICAN RADIATOR COMPANY

Ideal Boilers and American Radiators for every heating need

104 West 42nd St., Dept. T-183
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29 West 39th Street New York

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Baltimore
Birmingham
Boston
Bridgeport
Buffalo
Carolinas Section
  Charlotte Branch
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  Raleigh Branch
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Colorado
  Denver
Columbus
Detroit
Eastern New York
  Schenectady Branch
Erie
Hartford
Houston
Indianapolis
Inland Empire
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Kansas City
Knoxville
Lehigh Valley
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Los Angeles
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Memphis
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Mid Continent
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  Lincoln
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North Texas
  (Dallas)
Ontario
  Toronto
Oregon
  Portland
Peninsula (Grand Rapids)
Philadelphia
Pittsburgh
Plainfield
Providence
Rochester
St. Louis
St. Paul
San Francisco
Syracuse
Toledo
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Waterbury
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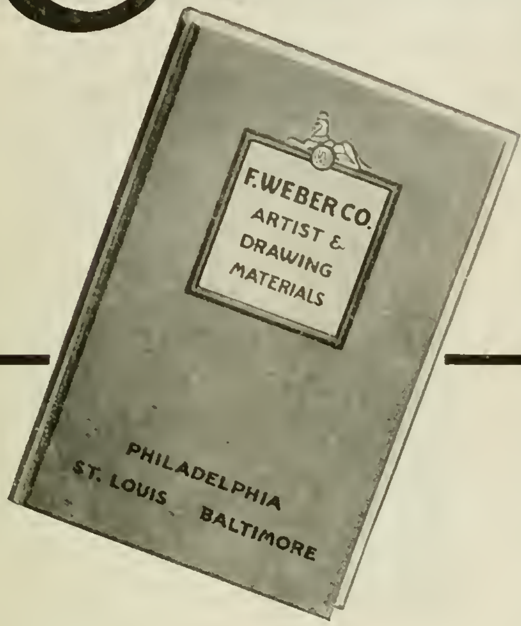
**Annual Meeting Dec. 1923
***Spring Meeting May 1924

Reports of these activities appear currently in the A.S.M.E. NEWS

Complete!



The New Weber Catalog

Complete in every sense of the word, the New Weber Catalog not only lists every known drawing room product, but also offers to you a new catalog service. As a time and labor saver as well as an assurance of getting just what you want when you want it, you will find this convenient purchasing plan invaluable in your ordering.

In this complete listing of drawing room supplies, many products are in every-day demand. These products can be purchased either through our dealers or direct from our factory. On the other hand, there are those products with a scattered demand that must be obtained direct.

It is the policy of this company to give prompt and careful attention to all mail orders and inquiries. Write today to Dept. ME for the New Weber Catalog.

F. WEBER CO.
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Cataloged Drawing Materials

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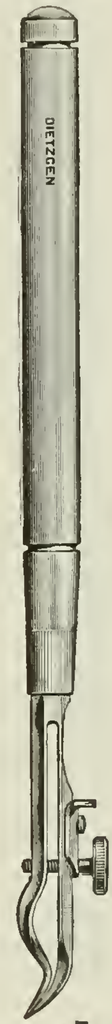
to nearest branch.
Quote on Shepard pens.

Name ....

Address ....

For block letters and border lines use Shepard Pen



Even for a skilled draftsman, the forming of heavy letters with a fine pen is slow and tiresome work.

Outlining is necessary, care is required, and the constant filling of the fine pen is annoying.

Why not do this kind of work in the quick, more mechanical way—easily, satisfactorily, accurately?

With the Shepard Lettering Pens, block letters are formed with a *single* stroke, and even a beginner can do lettering that fully satisfies.

Prove these merits by trial:

1. Easy to use
2. Won't clog
3. Large capacity
4. Even ink flow
5. Uniform lines

Made of nickel silver and steel, with elektron handle, and furnished in six sizes.

Nos. 2 3 4 5 6 7

Fac-simile of lines made with the six sizes of pens.

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Right goods at right prices
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Professional Engineering Service

CLASSIFIED INDEX

Card announcements of the Engineers listed below will be found alphabetically arranged on the following pages: Consulting Engineers, Page 137; Patent Attorneys, Page 140.

—Maintenance Department
Collins, Hubert E.
Van Ness, Frank W. & Associates

Paper and Pulp
Wallace, Joseph H. & Co.

Patent Experts
Gooding, Chas. S.
Greenwood, T. T.
Wollheim, Walter E.

Patent Lawyers
Alexander & Dowell
Gooding, Chas. S.
Nikonow, J. P.
Wollheim, Walter E.

Petroleum
Roberts, C. B. Engineering Co.
—Analysis
Roberts, C. B. Engineering Co.

Powdered Coal
Muhlfeld, John E.

Power Generation
Stevens, John A.

Power Plant Equipment
Provident Engrg. Co.

Power Plants
Cary, Albert A.
Cheyney, A. R.
Griggs & Myers
McClellan & Junkersfeld
Main, Chas. T.
Moore, W. E. & Co.
Norton, Fred. E.
Pittelkow Heating & Engineering Co.
Stevens, John A.
Stone & Webster
Stumpf Una-Flow Engine Co. (Inc.)
Von Eltz, K.
Wells, Geo. E.
White, J. G. Engrg. Corpn.
—Construction
Norton, Fred. E.
Public Service Production Co.
—Design
Norton, Fred. E.
Public Service Production Co.
Stumpf Una-Flow Engine Co. (Inc.)
—Hydro-Electric
Freeman, Roger M.
—Operation
Norton, Fred. E.

Production
Bedaux, Chas. E. Co.
Conrad, W. L.
Gilbreth, Frank B. (Inc.)
Gosselin, Edward N.
Griffiths, Wm. H.
Lewis, Warren B.
Manly & Veal

Public Utilities
Stone & Webster

Publicity, Technical
Advertising Service Agency

Pulverized Fuel Equipment
Muhlfeld, John E.

Pumping Equipment
Provident Engrg. Co.

Railroads, Steam and Electric
McClellan & Junkersfeld
Muhlfeld, John E.
White, J. G. Engrg. Corp'n

Refrigeration
Griggs & Myers
Wells, Geo. E.

Research
Abbott, Wm. G Jr.
Avram, M. H. & Co.
Greenwood, T. T.

Rolling Mills
Moore, W. E. & Co.

Sheet Metal Stamping
Modern Engrg. Co.

Special Machinery
Abbott, Wm. G. Jr.
Dove-Smith & Son
Modern Engrg. Co.
Roe, Walter H.

Steel Forging Plants
Freeman, Roger M.
Kennedy, Julian

Structural
Wells, Geo. E.

Sugar Factories
Lewis, D. J. Jr.

Sugar Refineries
Lewis, D. J. Jr.

Tax Specialists
McCall, Brownell & Co. (Inc.)

Testing
—Electrical
Electrical Testing Lab.
—Laboratory
Electrical Testing Lab.

Textile Machinery
Cox, James W. Jr.

Textile Mills
Cox, James W. Jr.
Main, Chas. T.
Sirrine, J. E & Co.

Textile Processes
Cox, James W. Jr.

Tobacco Products Plants
Sirrine, J. E. & Co.

Tool Designing
Dove-Smith & Son
Modern Engrg. Co.

Trade Marks
Alexander & Dowell
Wollheim, Walter E.

Valuation
—Power Plants
Muhlfeld, John E.

Ventilation
Gerdes, Theo. R. N.
Reed Engineering Co.

Warehousing
Sirrine, J. E. & Co.

Water Power Developments
Ambursen Construction Co. (Inc.)
Stone & Webster

Water Purification
Griggs & Myers
Rice, Cyrus Wm. & Co.
Simsohn, Julian S.
Von Eltz, K.

Water Supply Systems
Rice, Cyrus, Wm. & Co.
Simsohn, Julian S.

Work Routing
Lane, H. M. Co.

CONSULTING ENGINEERS

ALPHABETICALLY ARRANGED

See pages 136 and 137 for Classified Index in which Engineers having cards are listed according to their specialties

W. G. ABBOTT, Jr.
Research Engineer
Development of Invention, Special Machinery and Industrial Processes, Chemical and Electrical.
Laboratory: WILTON, N. H.

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Details gladly furnished interested executives.

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Winston Building — Utica, N. Y.

Cards Continued on Next Page

Cards Continued on Next Page

Use high quality oils to reduce FRICTION—the unseen enemy of production in your plant.

PENNY-*shaving*—

a dangerous practice in plant management

Plant superintendent:	"Did you send to the express office for those new bearings?"
Engineer:	"Yes sir, and they have not come."
Plant superintendent:	"That means another day of shut-down?"
Engineer:	"Yes sir."
Plant superintendent:	"Exactly, what was the cause for those bearings burning out?"
Engineer:	"Poor oil, sir, and what's more, other bearings will go the same way because we are using the same oil on them."

SHAVING pennies with poor oil is costly practice when it comes to the lubrication of machinery that makes your products and your profits.

The use of high-grade oils brings infinitely greater credit to the management. And it is cheaper in the end.

For example, on the quantity of oil required make this comparison:

If, say, 100 gallons of "oil" at 30c a gallon would lubricate all your machinery for a week, and 100 gallons of the correct high-grade lubricating oil at 50c would lubricate for 2 weeks—which oil is the cheaper by the month?—by the year?

To the savings in oil consumption you can add the cost of repairs and shut-downs which correct lubrication prevents. Add the profits that accrue from the continuous operation of your individual machines. Add the savings in power costs—coal or electric current which correctly lubricated prime movers invariably produce. Add the slower depreciation of your equipment which high-grade oils, correctly applied, will insure.

In many plants the sum total of these savings more than wipes out the entire oil bill for the whole year.

No plant is too large, none too small to profit by our 57 years of specialized experience, our studies, our oils, and our service. Usually our representative can prescribe the correct oil on the day he calls. In large plants where operating conditions are more complex, we suggest a Lubrication Audit which is outlined in column at right.

If you wish to take out the cheapest kind of insurance on both your machinery and its faithful operation, we suggest that you get in touch with our nearest branch office.

GARGOYLE

Lubricating Oils

A grade for each type of service

VACUUM OIL COMPANY

THE

Lubrication Audit

EXPLAINED STEP BY STEP
(In Condensed Outline)

INSPECTION: A thoroughly experienced Vacuum Oil Company representative in cooperation with your plant engineer or superintendent makes a careful survey and record of your mechanical equipment and operating conditions.

RECOMMENDATIONS: We later specify, in a written report, the correct oil and correct application of the oil for the efficient and economical operation of each engine and machine.

This report is based on:—

(1) The inspection of the machines in your plant.

(2) Your operating conditions.

(3) Our 57 years of lubricating experience with all types of mechanical equipment under all kinds of operating conditions throughout the world.

(4) Our outstanding experience in manufacturing oils for every lubricating need.

CHECKING: If, following our recommendations in this Audit, you install our oils, periodical calls will be made to see that the desired results are continued.

FOR THE ABOVE FREE SERVICE address our nearest branch office.

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THE ENGINEERING INDEX

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THE ENGINEERING INDEX presents each month, in conveniently classified form, items descriptive of the articles appearing in the current issues of the world's engineering and scientific press of particular interest to mechanical engineers. At the end of the year the monthly installments are combined along with items dealing with civil, electrical, mining and other branches of engineering, and published in book form, this annual volume having regularly appeared since 1906. In the preparation of the Index by the engineering staff of The American Society of Mechanical Engineers some 1200 technical publications received by the Engineering Societies Library (New York) are regularly reviewed, thus bringing the great resources of that library to the entire engineering profession.

Photoprint copies (white printing on a black background) of any of the articles listed in the Index may be obtained at a price of 25 cents a page. When ordering photoprints identify the article by quoting from the Index item: (1) Title of article; (2) Name of periodical in which it appeared; (3) Volume, number, and date of publication of periodical; (4) Page numbers. A remittance of 25 cents a page should accompany the order. Order should be sent to the Engineering Societies Library, 29 West 39th Street, New York.

(See also page 730 of this issue for supplementary items.)

ABRASIVE WHEELS

Diamonds for Truing. Selection and Use of Diamonds for Dressing Grinding Wheels, Ward M. Robinson. Machy. (N. Y.), vol. 30, no. 2, Oct. 1923, pp. 133-136, 3 figs. Discusses general practice in handling this work and presents original information on use of truing diamonds.

Progress in Manufacture. Progress in Grinding Wheel Manufacture, P. H. Walker. Machy. (N. Y.), vol. 30, no. 2, Oct. 1923, pp. 102-103. Developments; records of performance; new developments in vitrified wheels; improvements in abrasives; advances in polishing grain.

ACCELEROMETERS

Impact-Measuring. Accelerometer for Measuring Impact, Earl B. Smith. Am. Soc. Testing Matls., advance paper, no. 74, for meeting June 25-29, 1923, 7 pp., 4 figs. Describes accelerometer of spring type, so constructed as to have eliminated effect of lag.

ACCIDENTS

Industrial. Industrial Accidents and Hygiene. Monthly Labor Rev., vol. 17, nos. 2 and 3, Aug. and Sept. 1923, pp. 163-175 and 134-142. Aug.: Quarry and metal-mine accidents in 1921; accidents in Portland cement and in metal and woodworking industries in 1922; accident prevention in foundries; diagnosis of CO poisoning; industrial eye injuries; report of Belgian Commission on use of lead in painting; causes and prevention of blindness in Great Britain; industrial accidents in Sweden in 1919. Sept. Health hazards in photo-engraving; hydrogen sulphide as industrial poison; metal-fume fever; effect of locomotive smoke on trainmen in railway tunnels.

AERONAUTICAL INSTRUMENTS

Altitude Instruments. Calculating Altitudes for Record Purposes, Charles H. Colvin. Aviation, vol. 15, no. 15, Oct. 8, 1923, p. 440. It is shown that height-measuring instruments, both barographs and altimeters, are quite adequate for purposes for which they are used.

Barograph. The De Bothezat Barograph, Type "A," W. F. Gerhardt. Air Service Information Circular, vol. 5, no. 439, May 1, 1923, 11 pp., 16 figs. Instrument consists of large silk bellows connected to expansion tank in which presence is automatically brought to atmospheric at limit of expansion by special valve and system of electrical contacts.

AIR COMPRESSORS

Crankless. A Crankless Air Compressor. Power, vol. 58, no. 14, Oct. 2, 1923, p. 530, 2 figs. Crankless engine designed by A. G. M. Michell, which is adaptable, with modification in valve gear to use as air compressor, uniflow steam engine, gas engine, etc.; details of compressor.

Diesel-Driven for Pumping Plant. Air-Lift Pumping by Diesel Compressor, P. M. Thayer. Power Plant Eng., vol. 27, no. 19, Oct. 1, 1923, pp. 994-996, 3 figs. City of Fond du Lac has reduced cost of pumping by addition of Diesel compressor unit to water plant.

AIR CONDITIONING

Humidifying Plants. Humidifying Plants in Textile Mills, P. Martell. Eng. Progress, vol. 4, no. 8, Aug. 1923, pp. 176-178, 5 figs. Importance of saturating air with moisture for manufacturing process and for sanitary conditions; types and individual parts of humidifying plants; moisture meters.

AIR PUMPS

Radojet. Steam Condensing Auxiliaries. Beama, vol. 13, no. 65, Sept. 1923, pp. 191-194, 5 figs. Describes Radojet air pump, principal characteristic of which is use of steam jets for removal of air; types; advantages; operation; Radojets with intercondensers; application in various industries.

AIRCRAFT

Airworthiness, Regulations for. Regulations Governing the Issuance of Certificates of Airworthiness of Aircraft in France. Nat. Advisory Committee for Aeronautics—Tech. Notes, no. 155, Aug. 1923, 46 pp. Regulations approved by Under Secretary of State for Aeronautics. Translated from Bul. de la Navigation Aérienne, Mar. 1923.

Altitude Determination. The Determination of the Altitude of Aircraft, W. G. Brombacher. Optical Soc. Am.—Jl., vol. 7, no. 9, Sept. 1923, pp. 719-724, 13 figs. Practical method of determining altitude of aircraft above surface of earth, based on relations of altitude to various properties of air.

AIRCRAFT CONSTRUCTION MATERIALS

Steels. Steel Structural Parts for Aircraft, Horace C. Knerr. Iron Age, vol. 112, no. 13, Sept. 27, 1923, pp. 816-820, 3 figs. Control in their heat treatment; alloy steels which have been adopted; use of metal in aircraft increasing.

AIRPLANE ENGINES

Absolute Ceiling, Determination of. Engine Performance and the Determination of Absolute Ceiling, Walter S. Diehl. Nat. Advisory Committee for Aeronautics—Report, no. 171, 1923, 12 pp., 5 figs. Brief study of variation of engine power with temperature and pressures.

Carburetors. See CARBURETORS.

AIRPLANE PROPELLERS

Design. Adaptation of Propellers to Airplanes (Adaptation des Hélices aux Avions), M. Lamé. Aérophile, vol. 31, no. 13-14, July 1-15, 1923, pp. 209-211. Relation and proper adjustment between engine, propeller and plane; power of propellers; power available and power used.

Model Tests, Analysis of. Analysis of Dr. Schaffran's Propeller Model Tests, Max M. Munk. Nat. Advisory Committee for Aeronautics—Tech. Notes, no. 158, Sept. 1923, 13 pp., 8 figs. Extension of author's analysis of Dr. Durand's propeller model tests, adding now the slip curves obtained from tests made with different arrangement of test and with propellers with more than two blades; series of tests now analyzed is said to be a very complete and systematic one.

AIRPLANES

Cox-Klemin Training. Static Test of the Cox-Klemin TW-2 Training Airplane, A. S. No. 68,540, D. B. Weaver. Air Service Information Circular, vol. 5, no. 437, May 1, 1923, 24 pp., 39 figs. Test conducted for purpose of determining structural strength of Cox-Klemin TW-2.

Curtiss-Navy Racer. Curtiss Plane, Pulitzer Race Winner, Embodies New Design Features. Automotive Industries, vol. 49, no. 15, Oct. 11, 1923, pp. 742-743, 3 figs. Controlling mechanism changed materially from last year's design; engine altered slightly; new duralumin propeller employed.

Gliders. Report on Gliders, J. A. Roché. Air Service Information Circular, vol. 5, no. 444, May 1, 1923, 13 pp., 10 figs. Purpose of report is to set forth clear and simple methods for analysis of glider performance on different kinds of winds; value of gliders to aeronautics; effect of topography on soaring; different types of gliders; criteria for selection of soaring site.

Huff-Daland Training. Huff-Daland Model TA6 Advanced Training Plane. Aviation, vol. 15, no. 14, Oct. 1, 1923, pp. 408-409, 2 figs. Safety, simplicity and ease of alignment and assembly chief features of new plane, equipped with 200-hp. Wright-Lawrance J1 radial engine.

Laird Limousine. The Laird Five-Passenger Limousine Plane. Aviation, vol. 15, no. 13, Sept. 24, 1923, p. 371, 1 fig. New cabin plane equipped with 300-hp. Packard engine.

Metal. Metal Aeroplane Construction, Hugo Junkers. Roy. Aeronautical Soc.—Jl., vol. 27, no. 153, Sept. 1923, pp. 406-449, 53 figs. Outline of author's work in development of metal-airplane construction; discusses evolution of his metal plane and method of proceedings and working adopted; advantages of metal construction.

Racing. How Modern Racing Planes are Developed, Frank H. Russell. Aviation, vol. 15, no. 13, Sept. 24, 1923, pp. 366-367, 3 figs. Short synopsis of procedure necessary to create machine as near perfect as possible in relatively short time.

Roll, Damping Factor in. Preliminary Study of the Damping Factor in Roll, James M. Shoemaker and John G. Lee. Nat. Advisory Committee for Aeronautics—Tech. Notes, no. 161, Oct. 1923, 23 pp., 6 figs. Theoretical discussion of damping factor in roll, together with results of wind-tunnel tests on continuous rolling of U. S. A.-30 airfoil.

Seaplanes. See SEAPLANES

Sport. The Small Mark Sport Airplane R III/23 (Das kleine Mark-Sportflugzeug "R III/23"), G. Reinhard. Motorwagen, vol. 26, no. 20, July 31, 1923, p. 327, 1 fig. A semi-overhung, strutless, one-seated machine with air-cooled two-cylinder four-stroke engine.

Stability. Dynamic Stability as Affected by the Longitudinal Moment of Inertia, Edwin B. Wilson. Nat. Advisory Committee for Aeronautics—Report, no. 172, 1923, 8 pp. Results of tests with experimental airplane; investigation of period, and damping; note on short oscillations; lateral stability.

Structural Parts. Fittings and Other Structural Parts of Airplanes, P. Eydam. Nat. Advisory Committee for Aeronautics—Tech. Notes, no. 160, Oct. 1923, 22 pp., 37 figs. Fittings for wing spar joints and for strut connections; internal bracing; bracing wires; control and landing gear. Translated from Technische Berichte, vol. 3, no. 6.

Wings. Comparing Aerodynamical Properties of Wings, W. Klemperer and T. Bienen. Aviation, vol. 15, no. 13, Sept. 24, 1923, pp. 368-370, 3 figs. With special reference to aspect ratio and parasite drag.

Wren. The "Wren" Light 'Plane. Flight, vol. 15, no. 34, Aug. 23, 1923, pp. 503-504, 3 figs. General arrangements "Wren" light airplane, fitted with 3-hp. A. B. C. engine. Maximum speed about 25 m. p. h.

AIRSHIPS

Italian. Latest Progress in Italy in the Technical Construction of Dirigibles (Sugli ultimi progressi realizzati in Italia nella tecnica costruttiva dei dirigibili), U. Nobile. Giornale del Genio Civile, vol. 61, no. 5, May 31, pp. 317-330, 19 figs. partly on

Note.—The abbreviations used in indexing are as follows:
Academy (Acad.)
American (Am.)
Associated (Assoc.)
Association (Assn.)
Bulletin (Bul.)
Bureau (Bur.)
Canadian (Can.)
Chemical or Chemistry (Chem.)
Electrical or Electric (Elec.)
Electrician (Elecn.)
Engineer[s] (Engr.[s])
Engineering (Eng.)
Gazette (Gaz.)
General (Gen.)
Geological (Geol.)
Heating (Heat.)
Industrial (Indus.)
Institute (Inst.)
Institution (Instn.)
International (Int.)
Journal (Jl.)
London (Lond.)
Machinery (Machy.)
Machinist (Mach.)
Magazine (Mag.)
Marine (Mar.)
Materials (Matls.)
Mechanical (Mech.)
Metallurgical (Met.)
Mining (Min.)
Municipal (Mun.)
National (Nat.)
New England (N. E.)
Proceedings (Proc.)
Record (Rec.)
Refrigerating (Refrig.)
Review (Rev.)
Railway (Ry.)
Scientific or Science (Sci.)
Society (Soc.)
State names (Ill., Minn., etc.)
Supplement (Supp.)
Transactions (Trans.)
United States (U. S.)
Ventilating (Vent.)
Western (West.)

Classified List of Mechanical Equipment

Manufactured by Firms Represented in MECHANICAL ENGINEERING

FOR ALPHABETICAL LIST OF ADVERTISERS, SEE PAGE 166

Accumulators, Hydraulic
Mackintosh-Hemphill Co.
* Worthington Pump & Mchry. Corp'n

Aftercoolers, Air
* Ingersoll-Rand Co.

Air Compressors, Receivers, etc.
(See Compressors, Receivers, etc., Air)

Air Conditioning Apparatus
* American Blower Co.
* Carrier Engineering Corp'n
* Clarage Fan Co.
* Sturtevant, B. F. Co.

Air-Jet Lifts
* Schutte & Koerting Co.

Air Washers
* American Blower Co.
* Carrier Engineering Corp'n
* Clarage Fan Co.
* Cooling Tower Co. (Inc.)
* Spray Engineering Co.
* Sturtevant, B. F. Co.

Ammeters
* Bristol Co.
* General Electric Co.
* Westinghouse Electric & Mfg. Co.
Weston Electrical Instrument Co.

Anemometers
* Taylor Instrument Cos.
Weber, F. Co. (Inc.)

Annealing
* American Metal Treatment Co.

Arches, Boiler Furnace
* Liptak Fire-Brick Arch Co.
* McLeod & Henry Co.
* Titusville Iron Works Co.

Arches, Fire Door
* McLeod & Henry Co.

Arches, Ignition (Flat Suspended)
* Combustion Engineering Corp'n
* Liptak Fire-Brick Arch Co.
* McLeod & Henry Co.

Asbestos Products
Johns-Manville (Inc.)

Ash Lifts, Telescopic
* Gillis & Geoghegan

Axles, Car
* Fuller-Lehigh Co.

Babbitt Metal
* Medart Co.
* Westinghouse Electric & Mfg. Co.

Ball Bearings, Gages, etc.
(See Bearings, Gages, Ball)

Balls, Brass and Bronze
* Gwilliam Co.

Balls, Steel
* Atlas Ball Co.
* Gwilliam Co.
* New Departure Mfg. Co.
* S K F Industries (Inc.)

Barometers
* American Schaeffer & Budenberg Corp'n
* Taylor Instrument Cos.

Barometers, Mercurial
* Tagliabue, C. J. Mfg. Co.

Bearings, Ball
Fafnir Bearing Co.
Gurney Ball Bearing Co.
* Gwilliam Co.
* New Departure Mfg. Co.
* Norma Co. of America
* S K F Industries (Inc.)
* U. S. Ball Bearing Mfg. Co.

Bearings, Radial Thrust
* New Departure Mfg. Co.

Bearing, Roller
* Gwilliam Co.
* Hyatt Roller Bearing Co.
* Norma Co. of America
* Royersford Fdry. & Mach. Co.
* Timken Roller Bearing Co.

Bearings, Self-Oiling
* Brown, A. & F. Co.
* Doehler Die-Casting Co.
* Falls Clutch & Machinery Co.
* Jones, W. A. Fdry. & Mach. Co.
Link-Belt Co.
* Royersford Fdry. & Mach. Co.
* Wood's, T. B. Sons Co.

Bearings, Thrust
Fafnir Bearing Co.
* General Electric Co.
* Gwilliam Co.
* Norma Co. of America
* S K F Industries (Inc.)
* Timken Roller Bearing Co.
* U. S. Ball Bearing Mfg. Co.

Belt Dressing
* Dixon, Joseph Crucible Co.
Texas Co.

Belt Fasteners
Flexible Steel Lacing Co.

Belt Lacing (Hinge)
Flexible Steel Lacing Co.

Belt Lacing, Steel
* Bristol Co.

Belt Tighteners
* Brown, A. & F. Co.
* Jones, W. A. Fdry. & Mach. Co.
Link-Belt Co.
* Medart Co.
* Smidth, F. L. & Co.
* Wood's, T. B Sons Co.

Belting, Canvas (Stitched)
* United States Rubber Co.

Belting, Conveyor
* Goodrich, B. F. Rubber Co.
* United States Rubber Co.

Belting, Elevator
* Goodrich, B. F. Rubber Co.
* United States Rubber Co.

Belting, Leather
American Sole & Belting Leather Tanners (Inc.)

Belting, Rubber
* Goodrich, B. F. Rubber Co.
* United States Rubber Co.

Benches, Work
Manufacturing Equip. & Engrg. Co.

Bending & Straightening Machines
* Long & Allstatter Co.

Bends, Pipe
* Frick Co. (Inc.)
* Vogt, Henry Machine Co.

Billets, Steel
* Timken Roller Bearing Co.

Bleaching Machinery
Philadelphia Drying Mchry. Co.

Blocks, Tackle
Clyde Iron Works Sales Co.
* Roebling's, John A. Sons Co.

Blowers, Centrifugal
* American Blower Co.
* Clarage Fan Co.
* Coppus Engineering Corp'n
* De Laval Steam Turbine Co.
* General Electric Co.
* Ingersoll-Rand Co.
* Kerr Turbine Co.
* Sturtevant, B. F. Co.
* Westinghouse Electric & Mfg. Co.

Blowers, Fan
* American Blower Co.
* Clarage Fan Co.
* Coppus Engineering Corp'n
* Green Fuel Economizer Co.
* Sturtevant, B. F. Co.

Blowers, Forge
* Sturtevant, B. F. Co.

Blowers, Pressure
* American Blower Co.
* Clarage Fan Co.
Lammert & Mann Co.
* Sturtevant, B. F. Co.

Blowers, Rotary
Lammert & Mann Co.
* Schutte & Koerting Co.
* Sturtevant, B. F. Co.

Blowers, Soot
Diamond Power Specialty Corp'n
* Sturtevant, B. F. Co.

Blowers, Steam Jet
* Schutte & Koerting Co.

Blowers, Turbine
* Coppus Engineering Corp'n
* Sturtevant, B. F. Co.

Blueing (Metal)
* American Metal Treatment Co.

Boards, Drawing
Dietzgen, Eugene Co.
Keuffel & Esser Co.
ParVell Laboratories
Weber, F. Co. (Inc.)

Boiler Baffles
* King Refractories Co. (Inc.)
* McLeod & Henry Co.

Boiler Compounds
* Dixon, Joseph Crucible Co.
Unisol Mfg. Co.

Boiler Coverings, Furnaces, Tube Cleaners, etc.
(See Coverings, Furnaces, Tube Cleaners, etc., Boiler)

Boiler Fronts
* Brownell Co.
* O'Brien, John Boiler Works Co.
* Titusville Iron Works Co.

Boiler Settings, Steel Cased
* Brownell Co.
* Casey-Hedges Co.
* McLeod & Henry Co.
* O'Brien, John Boiler Works Co.
* Vogt, Henry Machine Co.
* Walsh & Weidner Boiler Co.

Boilers, Heating
* Brownell Co.
* Casey-Hedges Co.
* Erie City Iron Works
Herbert Boiler Co.
* Keeler, E. Co.
* Leffel, James & Co.
Lidgerwood Mfg. Co.
* O'Brien, John Boiler Works Co.
* Titusville Iron Works Co.
* Union Iron Works
* Walsh & Weidner Boiler Co.

Boilers, Locomotive
* Brownell Co.
* Casey-Hedges Co.
* Keeler, E. Co.
* Leffel, James & Co.
* Titusville Iron Works Co.
* Union Iron Works
* Walsh & Weidner Boiler Co.

Boilers, Marine (Scotch)
* Brownell Co.
* Casey-Hedges Co.
* Leffel, James & Co.
* Titusville Iron Works Co.
* Walsh & Weidner Boiler Co.

Boilers, Marine (Water Tube)
* Babcock & Wilcox Co.
* Casey-Hedges Co.
* Connelly, D. Boiler Co.
* O'Brien, John Boiler Works Co.
* Springfield Boiler Co.
* Titusville Iron Works Co.
* Walsh & Weidner Boiler Co.
* Ward, Charles Engineering Wks.

Boilers, Portable
* Brownell Co.
* Casey-Hedges Co.
* Erie City Iron Works
* Frick Co. (Inc.)
Herbert Boiler Co.
* Keeler, E. Co.
* Leffel, James & Co.
Lidgerwood Mfg. Co.
* O'Brien, John Boiler Works Co.
* Titusville Iron Works Co.
* Union Iron Works
* Walsh & Weidner Boiler Co.

Boilers, Tubular (Horizontal Return)
* Bigelow Co.
* Brownell Co.
* Casey-Hedges Co.
* Cole, R. D. Mfg. Co.
* Connelly, D. Boiler Co.
* Erie City Iron Works
Herbert Boiler Co.
* Keeler, E. Co.
* Leffel, James & Co.
Lidgerwood Mfg. Co.
Morrison Boiler Co.
New Haven Boiler Works (Inc.)
* O'Brien, John Boiler Works Co.
* Titusville Iron Works Co.
* Union Iron Works
* Vogt, Henry Machine Co.
* Walsh & Weidner Boiler Co.
* Ward, Charles Engineering Wks.
* Webster, Howard J.
* Wickes Boiler Co.

Boilers, Tubular (Vertical Fire)
* Bigelow Co.
* Brownell Co.
* Casey-Hedges Co.
Clyde Iron Works Sales Co.
* Keeler, E. Co.
* Leffel, James & Co.
Lidgerwood Mfg. Co.
Morrison Boiler Co.
New Haven Boiler Works (Inc.)
* O'Brien, John Boiler Works Co.
* Titusville Iron Works Co.
* Union Iron Works
* Walsh & Weidner Boiler Co.

Boilers, Water Tube (Horizontal)
* Babcock & Wilcox Co.
* Casey-Hedges Co.
* Cole, R. D. Mfg. Co.
* Connelly, D. Boiler Co.
* Edge Moor Iron Co.
* Erie City Iron Works
Herbert Boiler Co.
* Keeler, E. Co.
* Ladd, George T. Co.
Morrison Boiler Co.
* O'Brien, John Boiler Works Co.
* Springfield Boiler Co.
* Union Iron Works
* Vogt, Henry Machine Co.
* Walsh & Weidner Boiler Co.
* Wickes Boiler Co.

Boilers, Water Tube (Inclined)
* Babcock & Wilcox Co.
* Bigelow Co.
* Casey-Hedges Co.
* Keeler, E. Co.
* Ladd, George T. Co.
Morrison Boiler Co.
* O'Brien, John Boiler Works Co.
* Vogt, Henry Machine Co.
* Walsh & Weidner Boiler Co.
* Ward, Charles Engineering Wks.

Boilers, Water Tube (Vertical)
* Babcock & Wilcox Co.
* Bigelow Co.
* Casey-Hedges Co.
* Erie City Iron Works
* Keeler, E. Co.
* Ladd, George T. Co.
Morrison Boiler Co.
* O'Brien, John Boiler Works Co.
* Walsh & Weidner Boiler Co.
* Wickes Boiler Co.

Boxes, Carbonizing
Driver-Harris Co.

Boxes, Case Hardening
Driver-Harris Co.

Brake Blocks
Johns-Manville (Inc.)

Brakes, Air
* Allis-Chalmers Mfg. Co.
* General Electric Co.

Brass Goods
* Scovill Mfg. Co.

Breechings, Smoke
* Brownell Co.
Morrison Boiler Co.
* Titusville Iron Works Co.
* Vogt, Henry Machine Co.

Brick, Fire
* Bernitz Furnace Appliance Co.
* Celite Products Co.
* Drake Non-Clinkering Furnace Block Co.
Keystone Refractories Co.
* King Refractories Co. (Inc.)
* McLeod & Henry Co.

Brick Insulating
* Celite Products Co.
* Quigley Furnace Specialties Co.

Bridges, Coal & Ore Handling
* Brown Hoisting Machinery Co.
Link-Belt Co.

Bridgewalls (Furnace)
* McLeod & Henry Co.

Buckets, Elevator
* Brown Hoisting Machinery Co.
Chain Belt Co.
* Gifford-Wood Co.
* Hendrick Mfg. Co.
* Jones, W. A. Fdry. & Mach. Co.
Link-Belt Co.

Buckets, Grab
* Brown Hoisting Machinery Co.
Clyde Iron Works Sales Co.
Lidgerwood Mfg. Co.
Link-Belt Co.

Buckets, Self-Dumping
* Brown Hoisting Machinery Co.
Clyde Iron Works Sales Co.
Link-Belt Co.

Burners, Oil
* Best, W. N. Corp'n
* Combustion Engineering Corp'n
Foerst, John & Sons
Morse Dry Dock & Repair Co. (Fuel Oil Engrg. Dept.)
* Schutte & Koerting Co.
* Spray Engineering Co.

Burners, Powdered Fuel
* Quigley Furnace Specialties Co.

*Catalogue data of firms marked * appear in the A.S.M.E. Condensed Catalogues of Mechanical Equipment, 1923-24 Volume*

supp. plate. Details of design, construction and equipment of S. C. A., O. S., P. M., and N. dirigibles, built by Stabilimento di Costruzioni Aeronautiche in Rome.

Transatlantic Service. A Transatlantic Airship Service, W. T. Blake. Discovery, vol. 4, no. 45, Sept. 1923, pp. 227–230, 3 figs. Plan for service between Europe and South America. Design of proposed ships.

ALLOY STEELS

Elements in, Influence of. Steel Alloys. Automobile Engr., vol. 13, no. 180, Sept. 1923, pp. 273–274. Notes on influence of various elements, including carbon, sulphur, manganese, phosphorus, vanadium, chromium and nickel.

[See also AIRCRAFT CONSTRUCTION MATERIALS, Steels.]

ALLOYS

Aluminum Bronze. See ALUMINUM BRONZE.

Bearing Metals. See BEARING METALS.

Brass. See BRASS.

Copper. See COPPER ALLOYS.

Duralumin. See DURALUMIN.

Gun Metal. See GUN METAL.

Magnesium. See MAGNESIUM ALLOYS.

Zinc. See ZINC ALLOYS.

ALUMINUM BRONZE

Cavities in. The Occurrence of Cavities in Aluminium Bronze, J. Gallibourg and A. Brizou. Foundry Trade Jl., vol. 28, no. 371, Sept. 27, 1923, pp. 368–369. Study of casting conditions and results arising from investigation; pouring methods. Translated from paper presented to Paris Foundry Congress.

APPRENTICES, TRAINING OF

Foundry. Training Foundry Apprentices at the Falk Corporation, H. A. Frommelt. Foundry Trade Jl., vol. 28, no. 369, Sept. 13, 1923, pp. 231–233. Program put into effect in plant of Falk Corp., which has a more or less general manufacturing engineering business, specializing in helical gears and railway castings; factors which have made training a success. Paper presented before Am. Foundrymen's Assn.

ASHES

Combustible Matter in. Combustible Matter in Boiler Ashes, W. S. Patterson. Chem. & Industry, vol. 42, no. 38, Sept. 21, 1923, pp. 904–906, 1 fig. Causes of "mechanical losses;" presents graph showing for different amounts of ash in coal the relationship between combustible matter in ashes and actual weight of ashes discharged.

AUTOMOBILE ENGINES

Cooling Systems. New Water-Steam Cooling System Operates Without Pump, C. I. Preston. Automotive Industries, vol. 49, no. 12, Sept. 20, 1923, pp. 581–582, 3 figs. Lowergan system can be used with either conventional forced or thermo-siphon circulation; condenser prevents loss of water; radiator is said to be uninjured by freezing and has device to facilitate thawing.

Crankless. The Michell Crankless Motor-Car Engine and Air Compressor. Engineering, vol. 116, no. 3014, Oct. 5, 1923, pp. 427–430, 10 figs. partly on p. 432. Details of engine as developed for automobile purposes, of 8-cylinder type designed to develop 35 b. hp. at 1250 r. p. m.; principle has also been developed in connection with design of air compressors.

Opposed-Piston. Scavenging-Piston Two-Stroke Engine (Spülkolben-Zweitakt-Motor), Hugo Ruppe. Motorwagen, vol. 26, no. 20, July 31, 1923, pp. 325–326, 5 figs. Describes new Bekamo engine developed by author, introducing automatic, opposed pump piston.

Wisconsin Motor Co. Six-Cylinder Passenger Car Engine Announced by Wisconsin. Automotive Industries, vol. 49, no. 13, Sept. 27, 1923, pp. 640–642, 3 figs. Has overhead valves, 3³/₈-in. bore and 5-in. stroke; rated at 75 hp. at 3000 r. p. m.; designed for high-class car.

AUTOMOBILE FUELS

Alcohol. Production of Industrial Alcohol (La préparation industrielle de l'alcool), Eug. Grandmougin. Génie Civil, vol. 83, nos. 9, 10 and 11, Sept. 1, 8 and 15, 1923, pp. 198–202, 224–228 and 246–248, 5 figs. Production of alcohol for use as motor fuel; describes fermentation and chemical processes.

France. The Problem of a National Motor Fuel in France. Société des Ingenieurs Civils de France—Mémoirs et Compte Rendu des Travaux, vol. 76, no. 1–3, Jan.-Mar. 1923. Includes following articles: Problem of a National Motor Fuel in France, Its Evolution and Present State, Daniel Berthelot, pp. 31–59; Problem of a National Motor Fuel, Its Scientific Bases, Georges Baume, pp. 60–80, 1 fig.; Tests Made by Compagnie Générale des Omnibus de Paris and Société des Transports en Commun de la Région Parisienne with a View to Using Motor Fuels with Alcohol Base, J. Peridier, pp. 81–149, 19 figs.; National Motor Fuel, E. Barbet, pp. 151–158; France's Motor Fuel Situation, A. Grebel, pp. 159–179, 2 figs.; Use of Naphthalene for Manufacture of a National Motor Fuel, L. Roman, pp. 180–208; The National Motor Fuel and Our Agricultural Resources, P. Verola, pp. 209–216; National Motor Fuel, René Le Grain, pp. 217–226, 2 figs.; Manufacture of Absolute Alcohol, J. Nourry, pp. 227–233, 1 fig.; National Motor Fuel or National Engine?, Marcel de Connick, pp. 234–241; How to Satisfy France's Motor Fuel Needs by Her Own Resources Alone, G. Patart, pp. 242–279, 3 figs. partly on supp. plate; National Motor Fuel (Conclusions), Daniel Berthelot, pp. 280–294, 3 figs.; and Power and Output of Light Motors Fed by Non-Detonating Fuels, F. Schwers, pp. 295–307, 1 fig.

Heavy-Oil. Heavy Oil for Motor Cars, A. Heller. Eng. Progress, vol. 4, no. 8, Aug. 1923, pp. 171–173, 6 figs. New service methods of Berlin Gen. Omnibus Co. and German State Post.

[See also BENZOL; GASOLINE; INTERNAL-COMBUSTION ENGINES, Fuels for.]

AUTOMOBILES

Austrian Steyr. The Steyr Chassis. Automobile Engr., vol. 13, no. 180, Sept. 1923, pp. 258–264, 13 figs. Six-cylinder Alpine Steyr car is Austrian production made by Oesterreichische Waffenfabriks-Gesellschaft. Details of engine, transmission, suspension, rear and front axles, steering, etc.

Axle Weights. Ascertaining Axle Weights, A. Lampert. Motor Transport (Lond.), vol. 37, no. 964, Aug. 20, 1923, pp. 233–234, 4 figs. Simple method of finding out how the gross load of a vehicle is distributed on its axles.

Berliet. The 15.9 Hp. Berliet Car. Auto-Motor Jl., vol. 28, no. 36, Sept. 6, 1923, pp. 749–752, 12 figs. French car of typical continental design; has monobloc 4-cylinder engine combined with clutch and gear.

Beverley-Barnes. The 24–80 Hp. Beverley-Barnes Straight-Eight Car. Autocar, vol. 51, no. 1457, Sept. 21, 1923, pp. 506–508, 6 figs. Has straight-eight engine, with unusual plug position.

Bianchi. The 15 Hp. 2-Litre Bianchi Car. Auto-Motor Jl., vol. 28, no. 38, Sept. 20, 1923, pp. 791–794, 11 figs. New model of well-known Italian car; gearbox, propeller torque tube and back axle are one unit with gear at forward end of torque tube.

Bodies. Light Weight with Endurance in Body Construction. Motor Transport (N. Y.), vol. 29, no. 4, Sept. 15, 1923, pp. 130–131, 3 figs. Plymetl, a material specially made to withstand unusual strains and weather. Has rust-resisting qualities and reduces chafing.

New Product May Solve Body Finishing Problem, O. H. Briggs. Automotive Mfr., vol. 65, no. 5, Aug. 1923, pp. 12–13. Durability, glass-like hardness, easy manipulation, high-varnish gloss or satin surface as desired, and quick drying are characteristics of Duco finish.

Brakes. Air Brakes Claimed to Increase Life of Facing and Drum. Motor Transport (N. Y.), vol. 29, no. 4, Sept. 15, 1923, pp. 126–127, 3 figs. Westinghouse device fitted with steel shoes and metal liners; under test shows material improvement in service; installation of air device requires no alterations in original chassis design.

Cadillac. New Cadillac Model Includes Radical Mechanical Changes. Automotive Mfr., vol. 65, no. 6, Sept. 1923, pp. 7–9, 3 figs. Four-wheel service brakes, entirely different engine balancing, lower chassis in 1924 model; superior coachwork.

Chassis, Long-Distance. A Long-Distance Coach Chassis. Motor Transport (Lond.), vol. 37, no. 964, Aug. 20, 1923, pp. 243–244, 2 figs. Six-cylinder, 4-wheel braked car adapted to standard and special body construction, and designed for comfortable riding.

Citroen, Care and Maintenance. Care and Maintenance of Citroën Cars. Autocar, vol. 51, nos. 1454 and 1455, Aug. 31 and Sept. 7, 1923, pp. 384–386 and 413–415, 10 figs. Attention necessary to secure best results; adjustments which may become necessary in course of usage.

Cooper. Characteristics of the 11 Hp. Cooper. Autocar, vol. 51, no. 1454, Aug. 31, 1923, pp. 389–390, 2 figs. Component-built vehicle with coventry Climax engine, 66 by 100-mm. bore and stroke, fitted with crankshaft carried on two ball bearings, detachable cylinder head and side valves, cooling being by thermo-siphon circulation through nickel-silver-cased radiator.

Gear Change. Gear-Changing Made Easy. Autocar, vol. 51, no. 1455, Sept. 7, 1923, pp. 411–412, 3 figs. Device with which it is impossible to make a bad gear change at any speed; known as Mitchell gear change.

German. The 6/18-Hp. Dixi Automobiles of the Eisenach Automobile Factory (Germany) (Der 6/18 PS-Dixi-Wagen der Fahrzeugfabrik Eisenach), A. Heller. Zeit. des Vereines deutscher Ingenieure, vol. 67, no. 39–40, Sept. 29, 1923, pp. 941–944, 15 figs. Details of chassis of sport two-seater. See also Motorwagen, vol. 26, no. 27, Sept. 30, 1923, pp. 410–414, 15 figs.

H. E. 2-Liter. The 2-Litre H. E. Car. Auto-Motor Jl., vol. 28, no. 37, Sept. 13, 1923, pp. 769–772, 13 figs. Equipped with 4-cylinder engine having 72.5-mm. bore and 120-mm. stroke; general arrangement includes monobloc engine and clutch as separate unit.

Headlighting-Device Performance. Illumination Diagrams for Showing Head-Lighting Device Performance, F. H. Ford. Soc. Automotive Engrs.—Jl., vol. 13, no. 4, Oct. 1923, pp. 333–337, 6 figs. Author recommends arrangement for denoting intensity by varying degrees of tint on surface of chart that is supposed to represent roadway; method of comparing devices by illumination charts that illustrate performance of headlighting devices.

Heim. Low Center of Gravity Features German Car. Automotive Industries, vol. 49, no. 12, Sept. 20, 1923, p. 575, 1 fig. In new Heim car, floor of body is brought down to level of running boards and bottom of underpan; seats lowered accordingly; frame is wide.

Lea-Francis. The 10 Hp. Lea-Francis Light Car. Auto-Motor Jl., vol. 28, no. 35, Aug. 30, 1923, pp. 727–730, 12 figs. New model with overhead valves and comfortable occasional four-seater body.

Oldsmobile. New Oldsmobile Model Has Six Cylinder L-Head Engine, W. L. Carver. Automotive Industries, vol. 49, no. 13, Sept. 27, 1923, pp. 634–639, 11 figs. Among characteristics are 3-speed gearset, tubular propeller shaft, fabric universal joints, and semi-floating rear axle.

Overland. Detachable Seats Are Chief Feature of New Overland Sedan. Automotive Industries, vol. 49, no. 14, Oct. 4, 1923, pp. 694–695, 3 figs. Interior can be used for various purposes; volume of space back of front seat is 50 cu. ft.; exterior construction is all steel, while top and interior are covered with Duratex.

Pneumatic Load Suspension. Pneumatic Load Suspension. Motor Transport (Lond.), vol. 37, no. 964, Aug. 20, 1923, pp. 230–231, 3 figs. Body and freight converted into live load by simple air cushion system; wide application to all types of vehicles.

Schneider. The 15 Hp. TH. Schneider. Auto-Motor Jl., vol. 28, no. 34, Aug. 23, 1923, pp. 705–708, 12 figs. French car with engine of 85-mm. bore and 140-mm. stroke, four-cylindered; engine, clutch and gear, with self-starter and dynamo, comprise single unit.

Sizaire. A Car Without Axles. Autocar, vol. 51, no. 1457, Sept. 21, 1923, pp. 516–517, 5 figs. New two-liter Sizaire, in which much weight is greatly reduced and comfort ensured by original system of suspension.

Streamline. Comparative Trial Trips with the Jaray Streamline Automobile (Vergleichsfahrten mit dem Jaray-Stromlinienwagen), R. Conrad. Motorwagen, vol. 26, no. 23–24, Aug. 31, 1923, pp. 355–363, 11 figs. Results show economic advantages of Jaray car over standard-type automobiles.

Sunbeam. The Latest 16–40 Hp. Sunbeam. Autocar, vol. 51, no. 1455, Sept. 7, 1923, pp. 432–433, 4 figs. Mechanical improvements introduced in touring car.

Wolseley. The New Wolseley Programme. Autocar, vol. 51, no. 1453, Aug. 24, 1923, pp. 333–337, 13 figs. New 15-hp. chassis, new 10-hp. four-seater, and greatly extended range of coachwork of the 14-hp. chassis. Six distinct 1924 models ranging from two to six cylinders.

AVIATION

Aerial Navigation. Aerial Navigation, A. P. Rowe. Roy. Aeronautical Soc.—Jl., vol. 27, no. 153, Sept. 1923, pp. 450–458, 7 figs. Discusses art of navigating craft over (1) land unknown to navigator; land which is not capable of being mapped, e.g., desert; (3) large areas of water; (4) land or sea, but above clouds, such that pilot may take advantage of favorable weather conditions, or, in time of war, may proceed to his object of attack without interference.

Air-Line Requirements. Technical-Commercial Airplane Data (Estudio Técnico-Comercial del Avión), Luis Roque Pellizzari. Ingenieria, vol. 27, no. 8, Aug. 1923, pp. 356–362, 2 figs. Describes airplane service between Buenos Aires and Montevideo; types of airplanes suitable; data for calculating airplane details for given carrying capacity.

Development in U. S. Navy. The Development of Aviation in the Fleet, DeWitt C. Ramsay. U. S. Nav. Inst.—Proc., vol. 49, no. 9, Sept. 1923, pp. 1395–1417, 2 figs. Discusses military defensive and offensive potentialities inherent in certain types of aircraft, their limits of usefulness as auxiliaries to various types of naval surface vessels and suggested methods of their employment in naval warfare; deals with scouting, bombing, torpedo, observation and combat planes, kite balloons and rigid airships.

B

BEARING METALS

Babbitt. The Influence of the Ratio of Length to Diameter in the Compression Testing of Babbitt Metals, John R. Freeman, Jr. and Paul F. Brandt. Am. Soc. Testing Matls.—advance paper, no. 26, for meeting June 25–29, 1923, 7 pp., 3 figs. Investigation to determine influence of ratio of length to diameter in compression tests of babbitt metals.

High Lead Content. Bearing Metals with High Lead Content (Hochbleihaltige Lagermetalle), G. v. Hanffstengel. Giesserei-Zeitung, vol. 20, no. 18, Aug. 15, 1923, pp. 344–345, 4 figs. Properties and use of such alloys; hardening of lead with light metals; thermit bearing metal; behavior of bearing metals in practice.

BEARINGS, BALL

Manufacture. Ball Bearings and How They Are Made, Robert G. Skerrett. Sci. Am., vol. 129, no. 5, Nov. 1923, pp. 330–331 and 375, 8 figs. Describes equipment and process of manufacture.

BELTING

Leather. A New Type of "V" Leather Belt. Power Engr., vol. 18, no. 210, Sept. 1923, pp. 331–332, 2 figs. Salient features and advantages of Brammer belting, constructed on fish-scale principle, comprising separate leather links varying from 3 to 5 in. in length.

Making Leather Belts Endless, Louis W. Arny. Power Plant Engr., vol. 27, no. 19, Oct. 1, 1923, pp. 977–981, 11 figs. Tools required; making laps, classes of belts to be made endless; making new belts endless; waterproofing belting cement; lubrication.

BENDING

Theory of. The Theory of Bending, William Hovgaard. Engineering, vol. 116, no. 3015, Oct. 12, 1923,

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CLASSIFIED LIST OF MECHANICAL EQUIPMENT

Alphabetical List on page 166

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pp. 478–480, 3 figs. Investigation led to what is believed to be new and fundamental proof of essential soundness of theory, justifying its extension to beams of non-homogeneous materials.

BENZOL

Motor. Comparative Engine Tests with Crude, Acid-Refined, and Silica-Gel Refined Motor Benzol, A. C. Fieldner and G. W. Jones. U. S. Bur. of Mines—Reports of Investigations, no. 2517, Aug. 1923, 3 pp. Investigation to determine possibility of using silica-gel as refining agent for motor benzol, and especially possibility of removing sulphur compounds and gum-forming constituents by such treatment.

BLAST FURNACES

Fuels for. Tests with Different Fuels in the Blast-Furnace Plant of Böhler Bros. & Co., in Vordernberg (Germany) (Ueber Versuche mit verschiedenen Brennstoffen bei der Hochofenanlage der Gebruder Böhler & Co., A.-G., in Vordernberg). Stahl u. Eisen, vol. 43, no. 38, Sept. 20, 1923, pp. 1215–1219, 2 figs. Difficulties in production of charcoal pig iron; combustion velocity of different blast furnace fuels; practical experiences with mixed fuels.

BLOWERS

Converter. Blowers for Large and Small Converters (Gebläse für Gross- und Kleinkonverter), Hubert Hermann. Giesserei-Zeitung, vol 20, no. 19, Sept. 1, 1923, pp. 371–373, 4 figs. Comparison of burning in shaft furnaces and in iron baths; requirements of converters; drive of small blowers.

BOILER FEEDWATER

Circuits. Boiler Feed Water Circuits, James G. Weir, Power Engr., vol. 18, no. 211, Oct. 1923, pp. 381–384, 12 figs. Discusses three possible sources from which water can absorb impurity, namely, condenser leakage, make-up supply, and absorption of air and other gases in feed reservoir. See also Engineer, vol. 136, no. 3536, Oct. 5, 1923, pp. 372–374, 15 figs.

Regulators. Feed Water Regulators. Eng. Rev. & Trader, vol. 37, no. 2, Aug. 1923, pp. 31 32, 3 figs. Describes thermofeed water regulator, consisting of float chamber and automatic regulating valve.

The Mercon Regulator. Power, vol. 58, no. 16, Oct. 16, 1923, p. 602, 3 figs. Excess-pressure regulator for both steam- and motor-driven boiler-feed pumps designed to maintain constant differential.

Treatment. Purification of Feedwater by the Kestner Method (Rening av matarvatten enlight Kestners metoder), Torsten Samson. Teknisk Tidskrift, vol. 53, nos. 11 and 16, Mar. 17 and Apr. 21, 1923, pp. (Mekanik) 31–34 and 42–44, 16 figs. Describes Kestner method depending on precipitation of calcium sulphate and magnesium chloride by means of soda; describes, as example, water softening in a plant of five boilers, each producing 24,000 kg. steam per hour at 20 atmos.

BOILER FURNACES

Air Preheating. Ljungström Air Heater (Le rechauffeur d'air Ljungström). Génie Civil, vol. 83, no. 10, Sept. 8, 1923, pp. 232–234, 7 figs. Preheating of air, using heat of flue gases, advantages; describes preheating plant at Holmens Bruks works in Sweden.

Flue-Dust Removal. Flue-Dust Removal by Suction (Saugluft-Flugaschenförderung), Rich. Baumann. Zeit. des Vereines deutscher Ingenieure, vol. 67, no. 39–40, Sept. 29, 1923, pp. 954–955, 7 figs. Describes method according to which red-hot ashes are removed from boilers while in operation, then cooled and, by mixing with water, changed into easily handled sludge; cleanliness and economy of process.

Oil-Fired. Furnace Setting for Oil-Fired Boilers, George C. Adams. Power, vol. 58, no. 14, Oct. 2, 1923, pp. 531–532, 1 fig. Describes furnace composed of two important parts, air spacing and vacuum pit; air spacing is composed of standard arch bricks set on large side.

Pulverized-Coal-Burning. Burning Pulverized Coal in the Cannon Radiating Furnace, H. B. Cannon. Combustion, vol. 9, no. 4, Oct. 1923, pp. 307–311, 4 figs. New type of boiler furnace designed to operate with pulverized fuel, in which combustion rate many times in excess of rate recommended at present has been maintained.

Smokeless Combustion. Smokeless Combustion in Boiler Furnaces, R. C. Demary. Combustion, vol. 9, no. 4, Oct. 1923, pp. 323–324. Points out importance of analysis of flue gases or proper draft.

BOILER OPERATION

Control. Modern Systems of Boiler Control, John B. C. Kershaw. Combustion, vol. 9, no. 3, Sept. 1923, pp. 232–239, 7 figs. Savings effected by use of testing instruments in boiler houses; bonus systems of control; application of control systems in different plants in Great Britain.

BOILER PLANTS

Efficiency, Improvement of. Building up Efficiency in Small Boiler Plants, R. C. Demary. Power Plant Eng., vol. 27, no. 20, Oct. 15, 1923, pp. 1020–1022, 2 figs. Notes on boiler settings, and boiler-room instruments.

Methods and Equipment Employed in Increasing the Economy of the Light and Power Plant in the Krupp-Gruson Works, Magdeburg (Arbeiten und Einrichtungen zur Hebung der Wirtschaftlichkeit des Licht- und Kraftwerkes im Krupp-Grusonwerk, Magdeburg), H. Zimmermann. Wärme, vol. 46, no. 31, Aug. 3, 1923, pp. 339–341. Fluctuations in load; enlargement of draft; reconstruction of furnaces; no-load losses; turbo-generator as phase displacer; measuring station and control of operation.

Heat Balance. The Calculation of Heat Balances of Boiler Plant, Chas. F. Wade. Elec. Rev., vol. 93, no. 2388, Aug. 31, 1923, pp. 309–310. Laboratory data and further information needed as basis for calculation.

Management. Power Plant Management, Robert June. Blast Furnace & Steel Plant, vol. 11, no. 10, Oct 1923, pp. 546–550, 4 figs. Efficient combustion practice; combustion losses and how to minimize them.

BOILER TUBES

Cleaning Blower. The "Parry" Boiler Tube Cleaning Blower. Engineer, vol. 136, no. 3535, Sept. 28, 1923, p. 350, 5 figs. Combination of De Laval steam nozzle with deflecting nozzle fitted with accurately machined guide vanes, which is mounted in boiler in such manner that it commands all tubes.

BOILERS

Locomotive. See LOCOMOTIVE BOILERS.

Waste-Heat. Boilers with Large Water Space and Waste-Heat Boilers (Grosswasserraum- und Abhitzekessel in der neueren Wärmetechnik), Friedrich Schulte. Wärme, vol. 46, nos. 34 and 35, Aug. 24 and 31, 1923, pp. 373–377 and 387 391, 11 figs. Recent investigations and conclusions and their application to steam boilers; utilization of radiation and contact heat; size of furnace and of radiated heating surfaces in flue and other boilers; application of laws of heat transmission to waste-heat boilers of different types; elimination of air from boiler feed-water.

Water Gages. The Pneumercator Distant-Reading Boiler Water-Gauge. Engineering, vol. 116, no. 3015, Oct. 12, 1923, pp. 460–461, 6 figs. Describes gage which works with cold water, which is distinct advantage over gages in which glasses are subject to temperature of steam; can be placed in practically any position where it is most convenient for observation.

BOILERS, WATER-TUBE

Vertical. Vertical Water-tube Boilers, F. Johnstone-Taylor. Colliery Guardian, vol. 126, no. 3274, Sept. 28, 1923, pp. 773–775, 9 figs. Notes on their construction and advantages.

BRAKES

Compound Lever to Increase Power. Increased Brake Power for Passenger and Freight Vehicles. Ry. Engr., vol. 44, no. 524, Sept. 1923, pp. 340–341 and 350, 3 figs. By use of compound lever described, increased vacuum brake power is obtained without additional or larger cylinders and increased hand brake power secured with present brake handles.

Kunze-Knorr. The Kunze-Knorr Brake for Goods Trains, Kurt Wiedemann. Eng. Progress, vol. 4, no. 7, July 1923, pp. 133–138, 14 figs. Non-automatic single-chamber air brake; double-chamber air brake; change-over freight-train and passenger-train brake; Knorr-Knorr freight-train brake; braking performance; results of experience.

Passenger-Train. Universal Brake Control and Other Types of Brakes. Ry. & Locomotive Eng., vol. 36, no. 10, Oct. 1923, pp. 329–331, 1 fig. (Abstract.) Report to Traveling Engrs.' Assn.

BRAKING

Regenerative. The Compound Characteristic in Regenerative Braking with Direct-Current Traction, M. G. Say and H. G. Frampton. Instn. Elec. Engrs.—Jl., vol. 61, no. 321, Aug. 1923, pp. 863–868, 10 figs. Deals with particular form of regenerative braking for d.c. trains, effected by application of differential compound field excitation to traction motors.

BRASS

Hardness. The Hardness of "Common High" Sheet Brass, Alvan L. Davis. Am. Soc. for Steel Treating, vol. 4, no. 3, Sept. 1923, pp. 348–352. Sets forth average hardness, as determined by various methods, and range in hardness to be expected in annealed and in hard-rolled sheet brass of various tempers.

BRONZES

Defective Castings. Defective Bronze Castings, Walter F. Buckley. Metal Industry (N. Y.), vol. 21, no. 9, Sept. 1923, p. 359. Explanation of various reasons responsible for their production in foundry and what should be done to minimize and prevent this condition.

BUSES

Trolley. Birmingham's Experiment with Trolley Omnibuses, Alfred Baker. Surveyor, vol. 64, no. 1650, Aug. 31, 1923, pp. 153–154, 1 fig. Reasons for adoption of new traction system in Birmingham, England, and description of equipment employed.

BUSHINGS

Bronze, Molding. Bronze Bushings, R. E. Search. Metal Industry (N. Y.), vol. 21, no. 9, Sept. 1923, pp. 356–357, 5 figs. Various methods of molding these castings. Translated and abstracted from Fonderie Moderne, Apr. 1923.

C

CABLEWAYS

Pipe Handling with. Aerial Conveying of Large Pipe for Pressure Conduits (Di un impianto di trasporto funicolare per la posa in opera di grosso tubi di condotta forzata), Michelini Mario. Ingegneria, vol. 2, no. 8, Aug. 1, 1923, pp. 211–216, 8 figs. Details of cableway construction executed by Ceretti and Tanfani in Milan for Hydroelectric Co. of Villeneuve and Borgofranco in Turin; calculations of power and machinery required.

CAR COUPLERS

Automatic. The Automatic Scharfenberg Coupling for Railway Cars, Gustav Laubenheimer. Eng. Progress, vol. 4, no. 7, July 1923, pp. 155 156, 11 figs. Rigid-type coupling without any locking device; coupling process; locking and disengaging of coupling advantages of Scharfenberg coupling.

CARBURETORS

Aircraft. Thermal Atomizing Carburetors (Les carburateurs à pulvérisation thermique). Aérophile, vol. 31, no. 13–14, July 1–15, 1923, pp. 212 213, 2 figs. Describes Le Grain carburetor adapted to aeronautical engines, designed to eliminate all dangers from back-fire of flame, and assuring complete atomizing of fuel.

CARS, COAL

Large German Types. Large Goods Cars for Mass Traffic, Gustav Laubenheimer. Eng. Progress, vol. 4, no. 7, July 1923, pp. 129 132, 9 figs. New German State railway uses freight cars with capacity of 50 tons of coal, or 40 tons of coke and automatic unloading device.

CARS, FREIGHT

Cast-Steel Underframe. One-Piece Cast Steel Freight Car Underframe. Ry. Rev., vol. 73, no. 13, Sept. 29, 1923, pp. 447–449, 6 figs. Southern Pacific standard double-sheathed box cars, equipped with cast-steel underframe, weigh 13.8 lb. per cu-ft. capacity.

Reinforced-Concrete. Freight Cars Made of Reinforced Concrete, H. Kleinlogel. Eng. Progress, vol. 4, no. 8, Aug. 1923, p. 164, 3 figs. Experiments and designs; reinforced-concrete cars heavier but cheaper than steel cars.

Truck-Frame Tests. Tests on Different Shaped Arch Bar Side Frames, Louis E. Ensley. Ry. Mech. Engr., vol. 97, no. 9, Sept. 1923, pp. 632–634, 8 figs. Slight changes in design reduce unit stresses from over 40,000 lb. to about 20,000 lb. See also Ry. Rev., vol. 73, no. 9, Sept. 1, 1923, pp. 303–306, 8 figs.

CARS, PASSENGER

Construction Methods. Modern Methods in Railway Carriage Building. Engineering, vol. 116, no. 3015, Oct. 12, 1923, pp. 467–469, 9 figs. partly on supp. plate. Construction methods at Derby works of London Midland & Scottish railway.

Steel. Suburban Car Featured by Low Unit Weight. Ry. Mech. Engr., vol. 97, no. 9, Sept. 1923, pp. 637–639, 8 figs. New Rock Island steel coach weighs only 920 lb. per seated passenger; special lighting equipment.

CARS, REFRIGERATOR

German. The Refrigerator Cars of the German Railways, G. Reder. Eng. Progress, vol. 4, no. 7, July 1923, pp. 146–147, 2 figs. Describes design and equipment of new German type, design of which is based on experience made in America.

CASE-HARDENING

Protection from Carburization. Protective Coatings for Selective Carburization, J. S. Vanick and H. K. Herschman. Am. Soc. for Steel Treating—Trans., vol. 4, no. 3, Sept. 1923, pp. 305–328, 8 figs. Results of experiments with coatings of copper plate and mineral base pastes, such as kaolin, fireclay and enamel mixtures in order to find effective protection of steel surfaces from carburization.

CAST IRON

Mass Effect. Studies Mass Effect on Iron, O. Smalley. Foundry, vol. 51, no. 20, Oct. 15, 1923, pp. 822–825, 4 figs. Tests made to determine chemical and physical phenomena occurring in cast iron as affected by rate of cooling; pouring temperature and rate of filling mold shown to be factors. (Abstract.) Paper read at Int. Foundrymen's Congress. See also Foundry Trade Jl., vol. 28, no. 370, Sept. 20, 1923, pp. 246–250, 9 figs.

Pearlitic. The Production, Strength Properties and Useful Possibilities of Pearlitic Cast Iron (Das Perlitgusseisen, seine Herstellung, Festigkeitseigenschaften und Anwendungsmöglichkeiten), O. Bauer. Giesserei-Zietung, vol. 20, no. 17, Aug. 1, 1923, pp. 317–324, 10 figs. Conditions for production of pearlitic castings; tests to determine properties of pearlitic cast iron; its superiority over other kinds of cast iron, uses.

Specifications. Topical Discussion: Is It Desirable to Include Chemical Requirements in Specifications for Cast Iron? Am. Soc. Testing Matls.—advance paper, no. 23, for meeting June 25–29, 1923, 6 pp. Argument for affirmative, by Robert Job; argument for negative, by Richard Moldenke.

Testing. Testing Cast-Iron, Richard Moldenke. Foundry Trade Jl., vol. 28, no. 369, Sept. 13, 1923, pp. 224–226. Present position; Fremont test; early methods; separately cast test bars; advent of arbitration bar; necessity for universal bar; ring test; flat and round test bars; criticism of arbitration bar; diameter and machining of test bars; position of casting, etc. Report to Int. Foundrymen's Convention at Paris, France.

The Mechanical Testing of Cast Iron, H. H. Shepherd. Metal Industry (Lond.), vol. 23, nos. 9, 11, 12 and 13, Aug. 31, Sept. 14, 21 and 28, 1923, pp. 171–172, 223–225, 251–253 and 275–277, 7 figs. Reviews and criticizes various methods used for mechanical testing.

CASTING

Centrifugal. Centrifugal Casting Process. Machy. (Lond.), vol. 22, no. 569, Aug. 23, 1923, pp. 653–

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658, 9 figs. Machines and special melting plant used by Centrifugal Castings, Ltd., Kilmarnock.

Temperature Influence on Metals. The Influence of Casting Temperature on the Working Properties of Metals, T. B. L. Cain. Metal Industry (Lond.), vol. 23, no. 9, Aug. 31, 1923, pp. 165-166, 7 figs. Gives instances of profound influence excited by casting temperature.

CASTINGS

Cleaning. Machines and Methods for Cleaning Castings (Maschinen und Verfahren der Gussputzerei), W. Kaempfer. Zeit. des Vereines deutscher Ingenieure, vol. 67, nos. 35 and 36, Sept. 1 and 8, 1923, pp. 850-853 and 879-881, 31 figs. Comparison of sand blast and manual operations; free jet blasts; sand blasts with revolving tables; cleaning drums; handling of mass articles; dust absorption.

Small, Defects in. Common Defects in Small Important Castings, S. G. Smith. Foundry, Trade Jl., vol. 28, nos. 364 and 366, Aug. 9 and 23, 1923, pp. 119-120 and 168, 4 figs. Outline of few of numerous small parts for engines which give trouble and dissatisfaction when passing through operations in machine shop.

CENTRAL STATIONS

By-Product Power from Steel Works for. Central-Station Utilization of By-product Power from Steel Plants, L. B. Breedlove. Elec. World, vol. 82, no. 15, Oct. 13, 1923, pp. 761-762, 1 fig. Opportunity for economical interchange of electrical energy and conservation of waste heat developed in steel industry; what data obtained from fully electrified plant show.

Gas-Engine-Driven. The Gas Engine Power Station of Palmers' Shipbuilding and Iron Company. Engineering, vol. 116, nos. 3007, 3010, 3012 and 3015, Aug. 17, Sept. 7, 21 and Oct. 12, 1923, pp. 195-198 and 208, 288-292, 364-366 and 368, and 454-457, 43 figs. partly on supp. plates. Installation made at Jarrow-on-Tyne yard (England); station contains seven vertical tandem gas engines of 1500 b.hp. and one of 1000 b.hp., each engine being direct-coupled to electric generator. Details of switchgear installation.

Germany. Hirschfelde Central Station (Das Grosskraftwerk Hirschfelde), Hanno Zeuner. Elektro-Journal, vol. 3, no. 8-9, Aug.-Sept. 1923, pp. 142-165, 36 figs. Describes superpower station at Hirschfelde, in Saxony, including mechanical and electrical equipment; linking-up of power stations in Saxony.

CHROME-NICKEL STEEL

Corrosion, Resistance to. Resistance to Corrosion of a Nickel-Chrome Steel (La résistance à la corrosion d'un acier au nickel-chrome), Robert Stumper. Revue de Métallurgie, vol. 20, no. 9, Sept. 1923, pp. 620-621. Results of tests with a steel of following composition: 0.54 Si, 0.012 P, 0.65 Mn, 0.6 C, 15.68 Cr, 7.04 Ni, exposed to action of hydrochloric acid, sulphuric acid NaCl, steam, air, etc., showing excellent results.

CLUTCHES

Centrifugal. Centrifugal Clutches—II. Practical Engr., vol. 68, no. 1904, Aug. 23, 1923, pp. 103-104, figs. 12-17. Uses of centrifugal clutches; comparison of types.

COAL

Classification and Analyses. What Management Should Know of Coal, Robert June. Blast Furnace & Steel Plant, vol. 11, no. 9, Sept. 1923, pp. 495-499 and 503, 3 figs. Analytical summary of many elements entering into power production reduced to common basis for busy executive.

Direct Conversion to Electricity. Transforming Fuel Energy Directly Into Electric Energy [Problemet att direkt omvandla bränsleenergi till elektrisk (bränsleceller)], Gösta Angel. Teknisk Tidskrift, vol. 53, nos. 10 and 15, Mar. 10 and Apr. 14, 1923, pp. (Kemi) 13-16 and 17-20, 4 figs. By using coal as anode in Lalande battery, which is described in detail; describes gas battery with both electrodes consisting of gas, cathode connected with air, and anode with CO or other gas; concludes that at present direct transformation is impracticable.

Purchasing by Analysis. Propose Coal Buying by Analysis. Iron Trade Rev., vol. 73, no. 13, Sept. 27, 1923, p. 889. Southern Ohio Iron & Coke Assn. sponsors marketing plan in fuel similar to that in iron ore.

COAL HANDLING

Belt-Conveyor System. Coal Sorted, Stored and Transported by Belt-Conveyor System. Power, vol. 58, no. 16, Oct. 16, 1923, pp. 598-602, 7 figs. Fifty-ft. depth of coal storage is made possible by conveyor system, which may screen incoming coal, sending fine to power-house bunkers and coarser lumps to storage area; distributing crane performs number of functions in selecting and handling fuel; atomized water spray arrests coal dust.

Floating Plants. Floating Coal-Handling Plants at Continental Seaports, E. Krahnen. Iron & Coal Trades Rev., vol. 107, no. 2895, Aug. 24, 1923, p. 261. Floating steam slewing cranes for discharging and coaling steamers at Rotterdam; coal hoist for coaling steamers at Hamburg; coal hoist designed as colliers for coaling steamers.

Piers. The Electrically-Operated Coal Pier of the Western Maryland Railway Company, R. W. McNeill. Elec. Jl., vol. 20, no. 9, Sept. 1923, pp. 329-333, 8 figs. Equipment consists of stationary car dumper of lift and turnover type, with mechanical trimming apparatus for loading boats directly from dumper pan, and auxiliary conveying system to permit loading of boats on side of pier opposite that on which dumper pan is located.

COMBUSTION

CO at High Pressuree. Gaseous Combustion at High Pressures, William A. Bone, Dudley M. Newitt, and Donald T. A. Townend. Roy. Soc.—Proc., vol. 103, no. A721, May 3, 1923, pp. 205-232, 12 figs. Energy-absorbing function and activation of nitrogen in combustion of carbon monoxide.

The Relative Influences of Water Vapor and Hydrogen upon the Explosion of Carbon Monoxide—Air Mixtures at High Pressures, William A. Bone, Dudley M. Newitt, and Donald T. A. Townend. Chem. Soc.—Jl., vol. 123-124, no. 730, Aug. 1923, pp. 2008-2021, 2 figs. Describes experiments which have led to belief that water vapor has smaller influence than hydrogen upon rate of pressure development in carbon monoxide-air experiments.

COMPRESSED AIR

Foundries. Possibilities of Saving by Use of Compressed Air in Foundries (Ersparnismöglichkeiten im Pressluftbetrieb in Giessereien), H. Kupper. Giesserei-Zeitung, vol. 20, no. 19, Sept. 1, 1923, pp. 374-377, 3 figs. Conditions for economic working of compressors; use of compressors for low and high pressure in foundries; arguments for introduction of unit air pressure; proper design of compressed-air containers; arrangement.

CONDENSERS, STEAM

Air Pumps for. Air Pumps for Surface Condensers (Beurteilung von Luftpumpen für Oberflächenkondensatoren), Paul H. Müller. Schiffbau, vol. 24, no. 46, Aug. 15, 1923, pp. 717-718, 1 fig. It is shown that water-jet apparatus as air pumps for surface-condensing plants are more saving of heat and more practical than steam-jet apparatus.

Records. Condenser Records Show Air Leaks, Tube Scale or Good Performance, S. Thomas. Power, vol. 58, no. 15, Oct. 9, 1923, pp. 565-566, 1 fig. Refers to method of calculating results and interpreting condenser records described in previous issue (Sept. 11), and shows how it is applied in practice to 16,000-sq. ft. condenser serving 8000-kw. turbine.

Tubes, Testing. Testing Marine Condenser Tubes. Machy. (Lond.), vol. 22, no. 571, Sept. 6, 1923, pp. 728-729, 5 figs. Methods adopted in engine shops of William Beardmore & Co., Dalmuir.

Vacuum, Estimation of. Effect of Changing Conditions on Vacuum in Surface Condensers. Mech. World, vol. 74, no. 1913, Aug. 31, 1923, pp. 129-130. Method of calculation; includes table of vacuum, with corresponding temperatures.

CONNECTING RODS

Forked, Strength of. The Strength of Forked Connecting Rods, William J. Kerton. Engineering, vol. 116, no. 3014, Oct. 5, 1923, pp. 442-444, 7 figs. Author seeks to derive more accurate method of calculating stresses in forked end of connecting rod, and to prove validity of his method by experimental evidence. Paper read before Brit. Assn.

High-Speed Engines. The Design of Connecting-Rods for High-Speed Engines, M. Platt. Automobile Engr., vol. 13, no. 180, Sept. 1923, pp. 279-285, 15 figs., and (appendices), 285-287, 6 figs. Presents numerous formulas for design of connecting rods of various cross sections.

CONVEYORS

Mail Handling. Van Buren Station, Chicago Post Office. Am. Architect, vol. 124, no. 2426, Aug. 15, 1923, pp. 171-175, 10 figs. Mechanical conveyor system installed to handle large tonnage of mail.

Pneumatic. Compressed-Air and Fan Pneumatic Conveyor (Ueber Luft und Lüfterförderer), B. Buhle. Zeit. des Vereines deutscher Ingenieure, vol. 67, no. 36, Sept. 8, 1923, pp. 873-878, 35 figs. Fan-blast conveyor, in contrast to the usual suction and compressed-air conveyor, is described as an arrangement in which the air current is generated by a fan; describes types built by Seck Bros., Dresden, and Siemens-Schuckert Works, Berlin, and results of tests.

Safety Regulations. Safety Regulations for Conveyors. Iron & Coal Trades Rev., vol. 107, no. 2893, Aug. 10, 1923, p. 191. Recommended by S. Wales Miners' Federation.

COPPER ALLOYS

Copper-Nickel-Lead. Copper-Nickel-Lead Alloys (Kupfer-Nickel-Bleilegierungen), W. Guertler and F. Menzel. Zeit. für Metallkunde, vol. 15, no. 8, Aug. 1923, pp. 223-224, 2 figs. Whereas copper and lead as well as nickel and lead do not mix in every condition, by mixing of all three metals, technically useful alloys of uniform structure are obtained.

Copper-Tin. Solidification and Transformation Curves of Copper-Tin Alloys (Das Erstarrungs- und Umwandlungsschaubild der Kupfer-Zinnlegierungen), O. Bauer and O. Vollenbruck. Zeit. für Metallkunde, vol. 15, nos. 5 and 7, May and July 1923, pp. 119-125 and 191-195, 6 figs. Composition and properties of mixed crystals; changes in CuSn compound; eutectic points; etc.

CORROSION

Alloys Resistant to. Alloys Resistant to Corrosion. Faraday Soc.—Trans., vol. 19, part 1, no. 55, July 1923. Contains following papers: General discussion, by Robert Robertson and C. H. Desch, pp. 156-158; The Corrosion of Industrial Metals, W. H. Hatfield, pp. 159-168, 1 fig.; The Resistance to Corrosion of Stainless Steel and Iron, J. H. G. Monypenny; pp. 169-183, 4 figs. Heat and Acid Resisting Alloys (Ni—Cr—Fe), J. Ferdinand Kayser, pp. 184-195, 6 figs.; Monel Metal, John Arnott, pp. 196-198; Corrosion Tests on Certain Nickel Alloys, F. Orme, pp. 199-200; Mechanism of So-Called "Dry Corrosion" of Metals, Ulick R. Evans, pp. 201-212; general discussion, pp. 213-230, 1 fig.

Iron and Steel. Report of Committee A-5 on Corrosion of Iron and Steel. Am. Soc. for Testing Matls.—advance paper, no. 11, for meeting June 25-29, 1923, 35 pp., 28 figs. Reports on inspection of Fort Sheridan, Pittsburgh and Annapolis tests; on total immersion tests; and on methods of sampling and analysis of metallic coated products.

Mechanism of. The Mechanism of Corrosion, John Johnston. Indus. & Eng. Chem., vol. 15, no. 9, Sept. 1923, pp. 904-905. Points out that more attention should be directed to what may be expected to happen at surface of separation, and formation and behavior of film or layer at metal surface under various conditions.

COST ACCOUNTING

Toy Industry. Charges and Costs in Toy Manufacture, Arthur Lazarus. Indus. Management (N. Y.), vol. 66, no. 4, Oct. 1923, pp. 243-246. Cost finding in highly seasonal industry.

CUTTING TOOLS

Stellite. Grinding and Inspecting Stellite Cutters, C. W. Metzger. Machy. (N. Y.), vol. 30, no. 2, Oct. 1923, pp. 125-127, 3 figs. Methods employed to obtain accurately ground stellite cutters of inserted-tooth type.

D

DIES

Combination Punches and. Combination Punches and Dies and Their Uses in Railroad Shops, Henry Otto. Ry. Jl., vol. 29, no. 9, Sept. 1923, pp. 26-28, 14 figs. Describes and illustrates articles made from scrap pieces of sheet steel and sheet copper.

Wire-Forming. Design of Wire-forming Dies, W. B. Greenleaf. Machy. (N. Y.), vol. 30, no. 2, Oct. 1923, pp. 96-97, 6 figs. Forming and twisting a loop; forming second loop and bend; final operations on file wire.

DIESEL ENGINES

Design. Modern Diesel Engines (Die Dieselmaschine der Gegenwart), II. Nägel. Zeit. des Vereines deutscher Ingenieure, vol. 67, nos. 28, 29, 30, 32 and 33, July 14, 21, 28, Aug. 11 and 18, 1923, pp. 677-685, 711-713, 725-735, 778-782 and 808-812, 128 figs. Review of development during past decade; constructional features of latest types by M. A. N., Deutz, Krupp, Sulzer, Deutsche Werke and Michel Motor companies; methods of eliminating air compressor, and latest experience in regard to use of heavy oils (of high ignition point); development of 2-stroke engines, with special reference to valve and port methods of admitting air for scavenging; solid injection without use of compressor, an economic necessity in small Diesel engines, and trend is towards elimination of compressors in large engines as well; use of residual oils of high boiling point said to offer economic advantages; Krupp "mushroom" piston, an important development; use of Diesel engines on locomotives, with special reference to use of Lentz hydraulic gear.

European Types. Europe Developing New Types of Diesel Engines. Mar. Eng. & Shipg. Age, vol. 28, no. 10, Oct. 1923, pp. 598-601, 9 figs. Manufacturers carrying out experimental work on double-acting, high-speed and compressorless types of engines.

M. A. N. German Two-Cycle Diesels. Gas & Oil Power, vol. 19, no. 217, Oct. 4, 1923, pp. 5-6, 3 figs. Features of 12,000-hp. 6-cylinder double-acting 2-cycle M. A. N. engine destroyed after Armistice.

Temperature Distribution and Heat Stresses. The Most Recent Investigations of Temperature and Heat Stresses in Internal-Combustion Engines (Die neuesten Forschungen über den Temperaturverlauf und die Wärmespannungen in Verbrennungsmotoren), H. Schmolke. Wärme, vol. 46, no. 30, July 27, 1923, pp. 327-330, 1 fig. Describes determination of periodical temperature oscillations in walls of Diesel engines, and method of calculation leading to determination of stationary temperature distribution and resulting heat stresses.

DRILLING MACHINES

Scientific Investigation. Drilling Machines (Bohrmaschinen), G. Schlesinger. Werkstattstechnik, vol. 17, nos. 14 and 15, July 15 and Aug. 1, 1923, pp. 417-447 and 449-480, 248 figs. Comparison of scientific calculation, measurement and practical design, based on study of drawings submitted by 17 German firms, all well-known makers of drilling machines. Deals with stresses occurring in drilling and their measurement; main drive of machine and its parts; screw-cutting arrangements; weight of machine in relation to power consumption and drilling pressure; shape and stress of supports or stands. Description of various types and makes.

DRILLS

Twist, Magnetic Analysis. Report of Committee A-8 on Magnetic Analysis. Am. Soc. Testing Matls.—advance paper, no. 13, for meeting June 25-29, 1923, 3 pp. Abstract of report on testing of twist drills.

DRYING

Methods and Apparatus. Industrial Drying—The Apparatus and How It Works, Lucien Buck. Chem. & Met. Eng., vol. 29, no. 14, Oct. 1, 1923, pp. 626-631, 4 figs. Notes on theory and design of driers, with examples from actual practices which show how drying problems are solved.

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DURALUMIN

Resistance to Alternating Stresses. Resistance of Manganese Bronze, Duralumin, and Electron Metal to Alternating Stresses, R. R. Moore, Am. Soc. Testing Matls., advance paper, no. 24, for meeting June 25-29, 1923, 17 pp., 8 figs. Results of investigation made by Engineering Division of Air Service at McCook Field, to determine endurance limit of duralumin bar stock as rolled, annealed and tempered; similar investigations on manganese bronze and electron metal are included.

DYNAMICS

Stroud System of Teaching. The Stroud System of Teaching Dynamics, James B. Henderson. Engineering, vol. 116, no. 3013, Sept. 28, 1923, pp. 409-410. Describes results obtained with Stroud system; author seeks to show that system is more logical than any other in that all other systems become special cases, and also that Stroud's artifices are valuable aids to accuracy in laboratory and in engineering workshop. Paper read before Brit. Assn.

E

ECONOMIZERS

Cast-Iron. Feed Heaters or Fuel Economizers, Chas. F. Wade. Power Engr., vol. 18, no. 210, Sept. 1923, pp. 342-343, 1 fig. Outstanding facts relating to design, erection and operation of ordinary cast-iron type of economizer.

EDUCATION, ENGINEERING

American Industry and. Engineering Education and American Industry. Nat. Indus. Conference Board—Special Report, no. 25, Aug. 1923, 25 pp., 4 figs. Need for trained leadership in industry; educational problem; responsibility of industry.

EDUCATION, INDUSTRIAL

School Courses. The Educational Courses of the German Committee for Technical Instruction (Die Lehrgänge des Deutschen Ausschusses für Technisches Schulwesen), C. Matschoss. Zeit. des Vereines deutscher Ingenieure, vol. 67, no. 35, Sept. 1, 1923, pp. 845-849, 18 figs. Gives examples of instruction sheets for machine builders, locksmiths, patternmakers, molders, forgers, etc.; how courses originated; further developments and possibilities of application.

ELECTRIC DRIVE

Power-Plant Auxiliaries. The Drive of Power Station Auxiliaries, L. Breach and H. Midgley. Instn. Elec. Engrs.—Jl., vol. 61, no. 321, Aug. 1923, pp. 829-845 and (discussion) 845-862, 9 figs. Deals only with supply of power for auxiliaries of modern power station; consideration of different types of auxiliaries used in station; different types of supplies available; suitability of different auxiliaries and supplies for various conditions of station working.

ELECTRIC FURNACES

Brass Melting. Applying the Induction Furnace to an Industrial Brass Foundry, J. G. Crawford. Elec. World, vol 82, no. 12, Sept. 22, 1923, pp. 586-588, 3 figs. Advantages of electric melting include economies in production, improved quality of poured metal, closer control of product and more favorable operating conditions; results of test run.

Current-Consumption Calculation. Calculation of Current Consumption in Electric Furnaces (Note sur le calcul des prises de courant dans les fours électriques), Alphonse Pasquier. Revue de Métallurgie, vol. 20, no. 9, Sept. 1923, pp. 591-596, 2 figs. Describes simple practical method of calculation applicable to metallic or carbon electrodes.

Fiat. New Design of Electric Furnaces. Eng. Progress, vol. 4, no. 8, Aug. 1923, pp 169-170, 2 figs. Improvements; arrangement of electrodes; 3-phase transformer; advantages of Fiat furnace.

Induction. Theory of High-Tension Induction Furnaces (Théorie du four à induction à haute fréquence), G. Riband. Journal de Physique et le Radium, vol. 4, no. 6, June 1923, pp. 185-197, 2 figs. Calculation of what efficiency of this type of furnace should be, i.e., ratio between calorific energy accumulated in substance and electric energy taken from high-frequency source, and factors influencing this efficiency.

Metal Industry. Electric Furnaces in the Metal Industry (Der Ofen mit elektrischer Beheizung in der Metallindustrie), Wintermeyer. Elektro-Journal, vol 3, no. 2, Feb. 1923, pp. 22-25, 7 figs. Reviews construction and operation of various types of arc and resistance furnaces; annealing and heating furnaces.

Non-Ferrous. Use of the Electric Furnace in Non-Ferrous Foundries and in Heat Treatment (L'emploi du four électrique en fonderie d'alliages et dans les traitements thermiques), M. Fourment. Société des Ingénieurs Civils de France—Mémoires et Compte Rendu des Travaux, vol. 76, no. 4-5, Apr.-May 1923, pp. 446-467, 15 figs. partly on supp. plate. Principles of resistance, induction and arc furnaces, and their advantages in non-ferrous foundry work; comparison of various types of furnaces; construction of electric furnaces for heat treatment.

Steel. Giving Flexibility to Electric Furnace Design, Frank Hodson. Can. Machy., vol. 30, no. 10, Sept. 6, 1923, pp. 37-38, 3 figs. Steelmaking furnaces built for Ford Motor Co. plant, of 60 to 80-ton capacity, provided with 8 electrodes.

Progress in Manufacture of Steel in the Electric Furnace (Les progrès de la fabrication de l'acier au four électrique), Clausel de Coussergues. Société des Ingénieurs Civils de France—Mémoires et Compte Rendu des Travaux, vol 76, no. 4-5, Apr.-May 1923, pp. 423-445, 6 figs. on supp. plate. Describes different types of resistance or induction, arc radiation, and arc conduction furnaces, single-, two-, and three-phase, efficiency, heat losses, current consumption, etc.

ELECTRIC LOCOMOTIVES

Gasoline-Electric Switching. New Gasoline-Electric Switching Locomotive Ry. Rev., vol. 73, no. 14, Oct. 6, 1923, pp. 488-489, 2 figs. Describes 40-ton unit constructed by Gen. Elec. Co., embodying improvements in design and construction over previous types.

Interurban Freight Service. Electric Locomotive for Interurban Freight Service. Elec. Ry. Jl., vol. 62, no. 10, Sept. 8, 1923, pp. 368-369, 2 figs. Field-control motors with forced ventilation give high continuous rating; locomotive will haul 1180 tons on level tangent track.

Single-Phase. Single-Phase Express Locomotives, Type 1C1, With Individual Axle Drive, Built by Ateliers Sécheron for Swiss Federal Railways (Locomotives monophasées pour express, type 1C1, à commande individuelle des essieux, construites par les Ateliers de Sécheron pour les Chemins de fer fédéraux suisses), J. Werz. Génie Civil, vol. 83, no. 11, Sept. 15, 1923, pp. 241-245, 14 figs. partly on supp. plate. Describes design, electric equipment, and gives dimensions; results of trials; maximum speed 90 km. p. h.

Switching. Results in Switching Service With Storage-Battery Locomotives on the Austrian Federal Railway (Ergebnisse im Verschubdienst mit Akkumulatorlokomotive auf den Oesterreichischen Bundesbahnen), Robert Meixner and Adalbert Wachlowski. Elektrotechnische Zeit., vol. 44, nos. 33 and 34, Aug. 16 and 23, 1923, pp. 777-779 and 810-813, 2 figs. Efficiency of electric switching in general and with storage-battery locomotives in particular; profitableness of electric switching as compared with steam-locomotive switching.

ELECTRIC RAILWAYS

Cars, Side-Entrance. Door Lock for Side-Entrance Cars. Elec. Ry. Jl., vol. 62, no. 12, Sept. 22, 1923, pp. 447-449, 5 figs. Air-operated locks and indicators being installed on doors of Hudson & Manhattan railroad cars.

Length of Trains. Length of Trains for Electric Rapid Transit Service (Die Zuglänge elektrischer Stadtschnellbahnen), Reufert. Zentralblatt der Bauverwaltung, vol. 43, no. 65-66, Aug. 15, 1923, pp. 386-388, 8 figs. Data on length of trains in various capitals; discusses most economic length of trains for distance between two states, making calculations for distance of 600 m. with a starting acceleration of 0.7 m. per sec. per sec. and a braking deceleration of 1.0 m. per sec. per sec.

ELECTRIC WELDING

Development and Prospects. Electric Welder Vs. Riveter. Sci. Am., vol. 129, no. 4, Oct. 1923, pp. 236 and 295, 6 figs. Past successes and future promises of electric welding.

Tanks. The Application of Electric Welding to Large Tank Construction, E. J. Rigby. Am. Welding Soc.—Jl., vol. 2, no. 8, Aug. 1923, pp. 14-24 5 figs. Describes methods adopted in repairing and constructing gasholders by Melbourne and Metropolitan Gas Co.

ELECTRIC WELDING, ARC

Corrosion, Effect on. The Metallographic Aspect of Arc Welded Joints, E. J. Rigby. Indus. Australian & Min. Standard, vol. 70, no. 1813, Aug. 30, 1923, pp. 328-330, 9 figs. Discusses effects of corrosion on welding, in connection with use of Quasi-Arc process of welding used in construction of gas holder in Melbourne.

EMPLOYEES

Educating in Fundamental Economics. Educating Workers in Fundamental Economics, Carl F. Dietz. Ry. Age, vol. 75, no. 14, Oct. 6, 1923, pp. 617-620, 1 fig. How to tell story clearly and in such a way that they can readily grasp it. (Abstract.) Address delivered before Chamber of Commerce.

EMPLOYMENT MANAGEMENT

White Motor Co. White Company Revises Shop Management, F. L. Prentiss. Iron Age, vol. 112, no. 15, Oct. 11, 1923, pp. 953-955. Bonus wage plan and other mechanisms adopted by truck manufacturer; personnel research department; provision for close touch with employees.

ENGINEERS

Chemical. The Aim and Function of the Chemical Engineer, W. H. Coleman. Chem. Age (Lond.), vol. 9, no. 219, Aug. 25, 1923, pp. 197-198. Points out essential function of chemical engineer, emphasizing importance of simplification of processes and insisting on factor of cost as well as of efficiency being taken into account.

ENGINEHOUSES

Repair Facilities, Improvements in. Improvement in Roundhouse Repair Facilities. Ry. Rev., vol. 73, no. 13, Sept. 29, 1923, pp. 453-455, 3 figs. Shows how installation of pillar cranes and drop pits, with which roundhouse on Southwestern railway system is equipped, can be applied to facilitate light and running repairs.

Turntable Tractors. Foolproof Tractors for Balanced Type Turntables. Ry. Elec. Engr., vol. 14, no. 9, Sept. 1923, pp. 279-281, 5 figs. Great Northern installs outfits which cannot be injured by adding weight or reversing motor.

EVAPORATORS

Prache & Bouillon. The Prache & Bouillon Evaporator. Power Engr., vol. 18, no. 210, Sept. 1923, pp. 346-347, 1 figs. Principle of and main method employed in evaporator as designed for provision of pure water for boiler plants.

F

FANS

Electrically Driven. Electric Drive for Centrifugal Fans, Blowers and Propeller Fans, Gordon Fox. Blast Furnace & Steel Plant, vol. 11, nos. 9 and 10, Sept. and Oct. 1923, pp. 469-471 and 530-532, 3 figs. Characteristics of fans operated at various percentages of rating with curves showing pressures, velocity heads, horsepower, etc.

Mine. High-Pressure Ventilating Fans, M. Mallécot Colliery Guardian, vol. 126, no. 3270, Aug. 31, 1923, p. 522, 2 figs. Examination of relative merits of two methods of ventilation.

Operation. Ventilation Problems, Walter S. Weeks. Eng. & Min. Jl.-Press, vol. 116, no. 10, Sept. 8, 1923, pp. 413-414, 4 figs. Discusses various factors in operation of fans.

FATIGUE

Industrial. Industrial Fatigue and Its Factors, C. E. A. Winslow. Forging—Stamping—Heat Treating, vol. 9, no. 9, Sept. 1923, pp. 380-381. Regulation of working day not only proves beneficial to employer but directly increases production; overheating of workroom affects efficiency.

FEEDWATER HEATERS

Locomotive. Locomotive Feed Water Heaters. Ry. & Locomotive Eng., vol. 38, no. 10, Oct. 1923, pp. 331-334. Closed-type and open-type heaters; exhaust-steam injector; tests; boiler checks; effect of bad water. Committee report to Traveling Engrs.' Assn.

FILES

Steel, Failure of. Some Causes for File Steel Failures, Arthur W. F. Green. Iron Age, vol. 112, no. 13, Sept. 27, 1923, pp. 811-815, 30 figs. Suggested means for prevention; conditions prevailing in rolling, forging and heat treatment of steel.

FIRE EXTINGUISHERS

Carbon Tetrachloride. Tests with Tetrachloride Extinguishers on Electric Fires, S. H. Katz, E. J. Gleim and J. J. Bloomfield. Fire & Water Eng., vol. 74, no. 10, Sept. 5, 1923, pp. 441-442 and 448-449, 2 figs. Effects produced under varying conditions; experiments on electric arcs; effects on human beings.

FIRE FIGHTING

High-Voltage-Wire Hazards. The Danger of High Voltage Wires in Fire Fighting, W. W. Stephen. Fire & Water Eng., vol. 74, no. 13, Sept. 26, 1923, pp. 635-636 and 653. Streams in vicinity of such heavily charged wires hazardous; heavy shocks received through streams on transformers.

FIRE PROTECTION

Well-Water System. A Novel Well Water Fire Protection System, H. C. Wetmore. Fire & Water Eng., vol. 74, no. 11, Sept. 12, 1923, pp. 505-506, 6 figs. How Key West, Fla., met puzzling situation; shallow salt wells supply water for fire pumpers; how wells are constructed.

FIREBRICK

Testing Insulating Value of. Testing the Comparative Insulating Value of Fire Brick, T. M. Caven. Combustion, vol. 9, no. 3, Sept. 1923, pp. 243-244. Description of simple method of making tests for thermal conductivity.

FLOW OF WATER

Pipes. An Experiment on the Flow of Water through a Circular Bend of Rectangular Section, Kazuo Kumabe. Soc. Mech. Engrs. Tokyo, Japan—Jl., vol. 26, no. 78, June 1923, pp. 49-67, 22 figs. on supp. plates. Distribution of pressure and velocity in circular bend of rectangular section of pipe. Value of experiment in regard to theory of water turbines having radial guide vanes.

FORGE SHOPS

Charger Manipulator. Forge Shop with Charger-Manipulator. Iron Age, vol. 112, no. 16, Oct. 18, 1923, pp. 1034-1036, 4 figs. Machine operates on turntable, with heating furnaces grouped radially about it; flexible heat-treating furnace a feature.

FOUNDRIES

American Practice. American Foundry Practice, Richard Moldenke. Foundry Trade Jl., vol. 28, no. 372, Oct. 4, 1923, pp 283-284 and (discussion) 284-285. Notes on recruiting labor; Pittsburgh castings; nomenclature of semi-steel; cost systems, research work; sulphur in cast iron; pig iron by fracture and analyses; foundry coke; question of sand; safety-first considerations; coöperative research; testing cast iron. Paper before Inst. Brit. Foundrymen.

Brass vs. Iron. Brass vs. Iron Foundries, Charles F. Hopkins. Metal Industry (N. Y.), vol. 21, no. 9, Sept. 1923, pp. 351-355, 3 figs. Difference between ferrous and non-ferrous metals, care of crucibles and brass-foundry practice. (Abstract.) Address before Phila. Foundrymen's Assn.

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Economics in Foundries, H. Kopper. Metal Industry (Lond.), vol. 23, no. 14, Oct. 5, 1923, pp. 289–291, 3 figs. In author's opinion question of uniform pressure for foundries is becoming of progressively increasing importance, reasons for which are enumerated. Translated from Giesserei-Zeitung.

French Practice. Impressions of French Foundries. Metal Industry (Lond.), vol. 23, no. 13, Sept. 28, 1923, pp. 267–268. Comparison with foundry practice in America and England; no important difference in method employed; employment of female labor; molding and mixing machines.

Hamburg, Germany. The Iron Foundries of Greater Hamburg (Die Eisengiessereien Gross-Hamburgs), Gustav Wöhrn and Otto Friedheim. Giesserei-Zeitung, vol. 20, no. 18, Aug. 15, 1923, pp. 335–337, 4 figs. Account of most important foundries and their special products.

Modern Practice. Traces Trend in Steel Foundries, Edgar A. Custer. Iron Trade Rev., vol. 73, no. 15, Oct. 11, 1923, pp. 1028–1030. Green sand molds, rammed hard, becoming more widely used; rigid and accurately machined flasks and equipment; field pointed out for making castings in dry sand cores.

Protection of Workmen. The Protection of Foundry Workmen (Arbeiterschutz in Giessereien). A. Holverscheid. Stahl u. Eisen, vol. 43, nos. 30 and 36, July 26 and Sept. 6, 1923, pp. 968–975 and 1157–1162. Accidents liable to occur in sand dressing, molding, and with drying oven, in smelting and casting, cleaning of castings, etc.; treatment of injured.

Steel. Farington Steel Foundry (England) Iron & Coal Trades Rev., vol. 107, no. 2896, Aug. 31, 1923, pp. 291–292, 3 figs. Details of layout and equipment.

New Steel Jobbing Foundry. Iron Age, vol. 112, no. 14, Oct. 4, 1923, pp. 884–887, 6 figs. Plant of Eastern Steel Castings at Newark uses both acid open-hearth and electric furnaces; exceptional light conditions.

FOUNDRY EQUIPMENT

Sand-and-Oil-Mixing Machine. Sand and Oil Mixing Machine. Machy. (Lond.), vol. 22, no. 574, Sept. 27, 1923, pp. 826–827, 3 figs. New type of machine for mixing sand and oil as used in foundry core making.

FUELS

Anthracite Substitutes. Anthracite Substitutes, O. P. Hood. U. S. Bur. of Mines—Reports of Investigations, no. 2519, Aug. 1923, 4 pp. Discusses use of coke, bituminous coal, briquets, oil, and gas as substitutes. See also report on Fuels Available for Domestic Use as Substitutes for Anthracite Coal, Rudolf Kudlich in Report of Investigations, no. 2520, Aug. 1923, 7 pp.

Coal vs. Oil. Will It Pay to Burn Oil Instead of Coal? W. F. Schaphorst. Ry. Mech. Engr., vol. 97, no. 9, Sept. 1923, p. 624, 1 fig. Presents chart for determining relative value of coal and fuel oil.

Technology. Notes on Recent Developments in Fuel Technology, R. Wigginton. Fuel in Sci. & Practice, vol. 2, no. 8, Sept. 1923, pp. 247–248. New oil meter; examination of oils; coal gas; coal production; combustion of nitrogen; peat and dopplerite; fuel from ashes; industrial oxygen; new flame safety lamp.

Use and Abuse. Fuel—Its Use and Abuse, R. H. Fernald. Engrs. & Eng., vol. 40, no. 9, Sept. 1923, pp. 227–235 and (discussion) 235–239, 7 figs. Deals with resources and consumption in United States of solid, liquid and gaseous fuels; summary of suggestions for conservation of fuel.

[See also COAL; LIGNITE; OIL FUEL; PULVERIZED COAL.]

G

GAGES

Standardization. The Question of Gages in Germany and Abroad (Der Stand der Passnogsfrage in Deutschland und im Auslande), K. Gramenz. Zeit. des Vereines deutscher Ingenieure, vol. 67, no. 25, June 23, 1923, pp. 605–612, 11 figs. Definition, classification, and standardization of gages in Germany, Austria, Holland, Sweden, England, United States and Russia.

GAS PRODUCERS

Ash-Fusion. Ash-Fusion Gas Producers (Il gasogeno a fusione delle ceneri), M. Servais. Metallurgia Italiana, vol. 15, no. 1, Jan. 1923, pp. 7–10. Experiments with gas producers with capacity for gasifying 200 tons in 24 hrs.; tables of data referred to 1 kg. of coke; heat balance, etc.

GASES

Mixtures, Pressures of. The Pressures of Gaseous Mixtures, Irvine Masson and L. G. F. Dolley. Roy. Soc.—Proc., vol. 103, no. A722, June 1, 1923, pp. 524–538, 2 figs. Results of investigations show that volume of mixture of argon and ethylene is usually markedly greater than sum of separate volumes, all being measured at one and same pressure (termed mixture pressure); at fixed molecular ratio (mass ratio), there is particular value of mixture pressure at which increase is greatest.

Specific Heats. Varying Specific Heats and Gas Engine Mixtures, Telford Petrie. Engineer, vol. 136, no. 3536, Oct. 5, 1923, pp. 361–362, 2 figs. Presents charts of specific heats at constant volume.

GASOLINE

Power-Producing Qualities. Preliminary Report of Power Producing Qualities of Certain Gasolines, Hugh M. Milton, Jr. Agricultural & Mech. College of Texas—Bul., vol. 8, no. 8, Aug. 1, 1922, 39 pp., 17 figs. Investigation of efficiency variations of four-cycle internal-combustion engine with different grades of petroleum products.

GEARS

Tooth Thickness, Measuring. Measuring Tooth Thickness of Involute Gears, Ernest Wildhaber. Am. Mach., vol. 59, no. 15, Oct. 11, 1923, pp. 551–552. New method which is not affected by errors in outside diameter; ordinary vernier caliper used; formula for standard measurement. See article by same author entitled Measuring the Tooth Thickness of Helical Involute Gears, in same journal, no. 16, Oct. 18, 1923, pp. 587–588, 2 figs.

Variable-Speed. Shifting Speeds With An Oil Pump, P. J. Risdon. Sci. Am., vol. 129, no. 5, Nov. 1923, pp. 334 and 376, 4 figs. Details of British variable-speed gear without gear wheels.

GOVERNORS

Close Regulation. Close Regulation, H. W. Phillips. Power, vol. 58, no. 13, Sept. 25, 1923, pp. 495–498, 2 figs. Points out that close regulation may involve mechanical disadvantages in prime mover, a geared electric motor or a boiler-draft regulating device.

GRINDING

Disk. Reducing Costs by Disk Grinding, Charles O. Herb. Machy. (N. Y.), vol. 30, no. 2, Oct. 1923, pp. 109–112, 8 figs. Typical examples of work finished on disk-grinding machines.

GRINDING MACHINES

Face-Grinding. Face-Grinding Machines. Machy. (Lond.), vol. 22, no. 573, Sept. 20, 1923, pp. 789–792, 8 figs. Heavy-duty machines of double- and single-ended types.

Gear. Pratt & Whitney Gear Tooth Grinding Machine, Ellsworth Sheldon. Am. Mach., vol. 59, no. 15, Oct. 11, 1923, pp. 535–540, 10 figs. Faces of grinding wheels represent tooth profiles of rack; ingenious adaptation of mechanical movement; true generating machine.

GUN METAL

Casting Test Specimens. Methods of Casting Test Specimens of Gun Metal, E. H. Dix, Jr. Am. Soc. Testing Matls. advance paper, no. 25, for meeting June 25–29, 1923, 12 pp., 6 figs. Experience of McCook Field foundry in connection with casting test bars of gun metal.

H

HACK-SAWING MACHINES

Power. Power Hacksaws and their Efficiency, H. J. Swanson. Machy. (N. Y.), vol. 30, no. 2, Oct. 1923, pp. 121–124, 1 fig. Types of saw blades; cutting speeds; saw blades for different kinds of service; feeds or pressures on blade; determining time required for sawing.

HANDLING MATERIALS

Chemical Plants. Transport Facilities in Chemical Works, Herbert Blyth. Chem. Age. (Lond.), vol. 9, no. 219, Aug. 25, 1923, pp. 192–194, 5 figs. Describes facilities at works of United Alkali Co. at Widnes.

Problems. What Is Your Material Handling Problem? E. T. Spidy. Can. Ry. Club—Official Proc., vol. 22, no. 6, Sept. 1923, pp. 20–30 and (discussion) 30–34. Discusses factors entering into movement of material, namely, management and labor, trucking system, material to be moved, conveyance, distance material has to be moved, and roadbed on which movement is made.

HARDNESS

Magnetic Testing. Magnetic Indications of Hardness and Brittleneness, A. V. de Forest. Am. Soc. for Steel Treating—Trans., vol. 4, no. 3, Sept. 1923, pp. 342–347, 1 fig. Describes recent developments.

HEAT TRANSMISSION

Thermal Conductivity. The Measurement of Thermal Conductivity, Ezer Griffiths and G. W. C. Kaye. Roy. Soc.—Proc., vol. 104, no. A724, Aug. 1, 1923, pp. 71–98, 12 figs. Describes three types of apparatus of "plate" type for rapid precision determination of thermal conductivities of materials of low conductivity.

HYDRAULIC ACCUMULATORS

Design. Design and Calculation of Hydraulic Accumulators (Entwerfen und Berechnen hydraulischer Akkumulatoren), A. Lambrette. Praktische Maschinen-Konstrukteur, vol. 56, no. 27, July 5, 1923, 4 pp., 6 figs. Calculation of cylinders, pistons, etc., for various pressures; control and safety devices; pumps; etc.

HYDRAULIC TURBINES

American and European. American and European Hydraulic Turbines (Amerikanische und europäische Wasserturbinen), V. Graf. Zeit. des Vereines deutscher Ingenieure, vol. 67, no. 37, Sept. 15, 1923, pp. 908–909. Reply to article by H. Birchard Taylor in Power, no. 12, June 1923, in which he compares progress in America and Europe in construction of hydroelectric plants.

Conical. High-Speed Conical Turbines (Ueber schnellaufende Konusturbinen), W. Zuppinger. Schweizerische Bauzeitung, vol. 82, no. 8, Aug. 25, 1923, pp. 97–101, 10 figs. Describes conical turbines constructed by Ateliers des Charmilles, Geneva, and explains principle upon which construction is based.

Kaplan. Development of Kaplan Turbine (Die Entwicklung der Kaplanturbine), Paul Walther. Elektro-Journal, vol. 3, no. 1, Jan. 1923, pp. 4–7, 12 figs. Results of braking tests carried out at technical laboratories in Germany, and of turbines constructed under license, showing increased efficiency (up to 92 per cent) and improvements made.

Pelton. New 26,000 Hp. Pelton Turbines at the Venaus Central [Les nouvelles turbines Pelton de 26,000 C. V. de la centrale de Venaus (Mont-Cenis)], J. Bondet. Houille Blanche, vol. 22, no. 183, July-Aug. 1923, pp. 121–125, 7 figs. These turbines are built by Riva Co., Milan, for head of 1100 m.; horizontal axis; details of design and operation.

Single-Runner Overhung Pelton Turbines. Engineering, vol. 116, no. 3015, Oct. 12, 1923, p. 461, 4 figs. partly on p. 464. Reaction turbines installed in power plant on Fagundes River, Brazil.

The Modern Pelton Wheel, F. Johnstone Taylor. Power Engr., vol. 18, nos. 209, 210 and 211, Aug., Sept. and Oct., 1923, pp. 298–300, 325–327 and 365–367, 20 figs. Its development and present-day construction. Describes some recent successful Pelton wheel plants.

HYDROELECTRIC DEVELOPMENTS

Japan. Power Plants in the Orient, S. Q. Hayes. Power Plant Eng., vol. 27, no. 19, Oct. 1, 1923, pp. 986–988, 6 figs. Review of recent power developments in Japan.

New York State. Beaver River Hydroelectric System, R. T. Livingston. Power Plant Eng., vol. 27, no. 20, Oct. 15, 1923, pp. 1015–1019, 11 figs. System composed of five small plants forms public service corporation called Northern New York Utilities, Inc., supplying electric light and power to majority of towns and cities in district and also to large number of paper mills.

HYDROELECTRIC PLANTS

Belfast. The Harbour Power Station, Belfast. Elec. Rev., vol. 93, no. 2387, Aug. 24, 1923, pp. 285–289, 15 figs. Provisions for electricity supply in Belfast. Description of new plant with present capacity of 24,500 kw., and possible capacity of 150,000 kw.

Economical Operation. Operating Hydro-Electric Plants To Obtain Most Economical Output, Ralph Brown. Power, vol. 58, no. 16, Oct. 16, 1923, pp. 614–616, 1 fig. Method of keeping record of plant performance to obtain best economy of available water; operating in parallel with steam plants; obtaining maximum output from hydroelectric units.

Italy. Piave-Santa Croce Hydroelectric Plants (Impianti idroelettrici Piave-Santa Croce), Carlo Semenza. Elettrotecnica, vol. 10, no. 26, Sept. 15, 1923, pp. 589–611, 43 figs. Piave-Santa Croce canal; describes Fadalto, Nove, San Floriano, Castelletto and Caneva plants.

Japan. A Great Japanese Power System, Ernest V. Pannell. Elec. Rev., vol. 93, no. 2389, Sept. 7, 1923, pp. 359–361, 5 figs. Details of Ohi hydroelectric plant, Osaka.

Sherman Island, Hudson River. Paper Company Completes Power Plant on the Hudson. Eng. News-Rec., vol. 91, no. 12, Sept. 20, 1923, pp. 470–476, 12 figs. Unusual geological condition of site; self-loading, multiple-arch dam; 864-ft. spillway; large concrete-lined canal; reinforced-concrete penstocks, scroll cases, and draft tubes.

Switzerland. The Ritom Hydroelectric Plant of the Swiss Federal Railway (Das Kraftwerk Ritom der S. B. B.), H. Eggenberger. Schweizerische Bauzeitung, vol. 81, nos. 20, 21, 22, 23, 24, 25 and 26, May 19, 26, June 2, 9, 16, 23 and 30, 1923, pp. 246–249, 255–256, 267–270, 287–289, 296–297, 305–308 and 318–321 and vol. 82, nos. 1, 5, 6 and 7, July 7, Aug. 4, 11 and 18, 1923, pp. 6–9, 65–66, 69–73 and 90–93, 94 figs. Part I: Hydraulic features: Constructional details; reservoir and dam; inlet tunnels; pressure pipe line; cableway. Part II: Mechanical and electrical details: Regulation of turbines; generators; transformers; switchgear; protective arrangements against overvoltage and excess-current; building and operating costs.

HYDROPLANES

Design. Hydroplanes (Note sur les hydroglisseurs), P. Boutiron. Bul. Technique du Bureau Veritas, vol. 5, no. 7, July 1923, pp. 142–147, 9 figs. A river or marine boat propelled by purely aerial means, which latter also sustain it in water; details of design and propulsion; discusses phenomenon of gliding and its practical application.

Development. Flying Boat or Hydroplane? (Flygbat eller flottörflygplan?), E. Meyer. Teknisk Tidskrift, vol. 53, no. 9, Mar. 3, 1923, pp. (Allmänna Avdelningen A) 65–67, 7 figs. Discusses development in Germany, and describes various types.

I

ICE PLANTS

Montgomery, Ala. Montgomery, Ala., Ice and Cold Storage Plant. Southern Engr., vol. 40, no. 1, Sept. 1923, pp. 61–64, 7 figs. Description of plant of Atlantic Ice & Coal Corp., which consists of three units, two 100-ton and one 40-ton capacity units; combined ice and cold storage plant.

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Oil-Engine Drive. Ice-Making with Oil Engines. Refrigeration, vol. 32, no. 6, July 1923, pp. 30 31, 5 figs. Plant in Jersey City which has normal daily capacity of 200 tons. Experimental work showed that oil-engine drive was most economical.

Oil- vs. Corliss-Engine-Driven. Comparative Cost[s] of Operating a 20-Ton Ice Plant. Southern Engr., vol. 40, no 1, Sept. 1923, pp. 50 52, 2 figs. Comparison of operating costs of a Diesel-oil-engine and a Corliss-engine-driven 20-ton plant.

INDICATORS

Micro, for High-Speed Engines. A New Type of High-Speed Engine Indicator. Power Engr., vol. 18, no. 210, Sept. 1923, pp. 351 352, 5 figs. Main features and advantages of Collins' patent micro-indicator, made by Cambridge & Paul Instrument Co.

INDUSTRIAL MANAGEMENT

Absence Records. Absence Records That Aid in Production Planning. Factory, vol. 31, no. 4, Oct. 1923, pp. 460–461, 500 and 502, 4 figs. Records of absenteeism collected from four large Philadelphia textile firms during over three years and dependable facts brought out by them.

Control Methods. The Control of an Industry in the Business Cycle, Howard Coonley. Taylor Soc.—Bul., vol. 8, no. 4, Aug. 1923, pp. 128–136, 5 figs. Methods employed in plants of Walworth Mfg. Co. Development of cost accounting, changes in organization, application of cycle theory and data to Walworth planning; budgetary control of sales, purchases, receipts, and expenditures.

Production Planning. Organization of Work at Factory Shop of the Arts & Métiers School at Paris (Organisation du travail dans l'atelier de fonderie de l'école d'Arts & Métiers de Paris), Gaston Vidal. Arts et Métiers, vol. 76, no. 34, July 1923, pp. 641–656. Details of work by students and sample forms used for workshop orders; finding cost production, etc.

INDUSTRIAL RELATIONS

Employers' Organizations. Employers' Associations in the United States. Int. Labour Rev., vol. 8, no. 3, Sept. 1923, pp. 367–379. Activities of employers' associations; U. S. Chamber of Commerce; Nat. Assn. of Mfrs.

Industrial Disputes, Settlement of. How Germany Settles Industrial Disputes, Emil Frankel. Monthly Labor Rev., vol. 17, no. 3, Sept. 1923, pp. 8–17. Legal conciliation agencies; jurisdiction, organization and procedure of conciliation boards; voluntary adjustment agencies; effectiveness of conciliation system; proposed measures for adjustment of disputes.

INDUSTRIAL TRUCKS

Electric. Electric Single-Axle Truck (Der Elektro-Einachs-Schlepper), Trautvetter. Elektro-Journal, vol. 3, no. 5, May 1923, pp. 93–95, 5 figs. A two-wheel truck with storage batteries at both sides of axle, having capacity of 3.5 hp. at 60 volts; battery capacity, 3 hr. uninterrupted work; can be used for street transportation, factory railways, in shunting yards, etc.

INTERNAL-COMBUSTION ENGINES

Crankless. Crankless Engines. Autocar, vol. 51, no. 1455, Sept. 7, 1923, p. 419, 3 figs. 8-cylinder design likely to be developed for aircraft use, and may also be applicable to automobile.

Fuel-Injection Pump. The Time Lag and Interval of Discharge with a Spring Actuated Fuel Injection Pump, Robertson Matthews and A. W. Gardiner. Nat. Advisory Committee for Aeronautics—Tech. Notes, no. 159, Sept. 1923, 17 figs., 1 fig. Deals with research on spring-actuated fuel pump for solid or airless-injection with small, high-speed internal-combustion engines.

Fuels for. Fuels for Internal Combustion Engines, with Special Reference to Alcohol Production, Frederick Nathan. Fuel in Sci. & Practice, vol. 2, no. 8, Sept. 1923, pp. 249–254. Survey of possible substitutes for gasoline for use in internal-combustion engines.

Heat Transmission in. Heat Transmission in Internal-Combustion Engines (Der Wärmeübergang in der Verbrennungskraftmaschine), Wilhelm Nusselt. Zeit. des Vereines deutscher Ingenieure, vol. 67, no. 28, July 14, 1923, pp. 692–695, 5 figs. Based on explosion tests in ball-shaped bombs, study is made of cooling of hot combustion gases; formulas for heat-transmission coefficients are derived; and equation is developed for calculation of heat exchange between gas and wall in internal-combustion engine.

High-Power. High-Power Explosion Engines (Moteurs à explosion à haut rendement), Maurice Dumas. Technique Moderne, vol. 15, no. 17, Sept. 1, 1923, pp. 530–534, 8 figs. Inadequacy of Rochas cycle; gives variation and dimensions; instead of cutting to dead point, stops short of it; gives illustrative examples.

Losses in. Losses in Heat Engines and Means of Reducing Them, W. P. Sillince. Diesel Engine Users Assn., Reprint Paper, for meeting June 8, 1923, 37 pp., including discussion, 8 figs. Reducing waste and improving efficiency of heat engines of internal-combustion, particularly Diesel type; principal losses of heat; typical Diesel-engine heat balance; losses to jacket water and exhaust; Still engines.

Research and Testing Plant. The Works and Laboratory of Messrs. Ricardo & Co., Ltd. Automobile Engr., vol. 13, no. 180, Sept. 1923, pp. 275–278, 10 figs. Résumé of activities at Bridge Works, Sussex; methods and equipment.

Swedish Two-Stroke. New Swedish Two-Stroke Internal-Combustion Engine With Direct Injection (En ny svensk tvatakts förbränningsmotor med direkt insprutning), Gunnar Dellner. Teknisk Tidskrift, vol. 53, no. 16, Apr. 21, 1923, pp. (Mekanik) 37 42, 9 figs. Design and construction of a high-pressure engine (minimum 28 kg. per sq. cm.) with direct injection, without compressed air.

[See also AIRPLANE ENGINES; AUTOMOBILE ENGINES; CARBURETORS; DIESEL ENGINES; MOTORCYCLES, Engines; OIL ENGINES.]

IRON CASTINGS

Chilled Rolls. Application of Scientific Principles to the Manufacture of Chilled Rolls, Emil Schutz. Foundry Trade Jl., vol. 28, no. 367, Aug. 30, 1923, pp. 176–179, 8 figs. Results of investigation of number of problems relating to manufacture of chilled rolls recently carried out in Germany; factors studies include cooling of rolls, heating of chills, contraction, chill, casting strains and temperature, hardness, and chemical and metallurgical properties of castings. Translated from Stahl u. Eisen

IRON, PIG

Electrolytic Production. Production of Pig Iron by the Electric Furnace (La fabrication de la fonte au four électrique), Clausel de Coussergues. Société des Ingénieurs Civils de France—Mémoires et Compte Rendu des Travaux, vol 76, no. 4–5, Apr.-May 1923, pp. 543–564. Describes different types of furnaces; reactions in electric blast furnaces, and reagents used; comparison of open and closed furnaces; future of pig iron production by electric furnace.

L

LABORATORIES

Aerodynamic. The Melbourne University Aerodynamic Laboratory, W. E. Bassett. Commonwealth Engr., vol. 10, no. 11, June 1, 1923, pp. 410–412, 4 figs. Designed to carry our research work on aircraft machine, engines, and construction material; for affording instruction to engineering students; testing accurate models of airplanes or airships; testing actual engines used as to horsepower developed, fuel consumption, faults, etc; and to advance technical knowledge of science of aeronautics.

LATHES

Locomotive Wheel Boss. Lathes for Locomotive Wheel Bosses (Lokomotivradsatz-Drehbank), H. Krupski. Zeit. des Vereines deutscher Ingenieure, vol. 67, no. 35, Sept. 1, 1923, pp. 858–861, 11 figs. Influence of attempts to increase efficiency on design of machine; principal parts, drive and feed; advantages of new lathe.

LIFTING MAGNETS

Raw-Material Handling. The Industrial Advantages of Electric Lifting Magnets, F. N. Reville. Australasian Elec. Times, vol. 2, no. 7, July 27, 1923, pp. 468 and 471–473, 2 figs. Description of magnets designed for handling raw material.

LIGNITE

U. S. Deposits. Neglected Sources of Home Supply of Liquid Fuel. Oil Eng. & Finance, vol. 4, no. 83, Aug. 11, 1923, pp. 141–142. Oil obtainable from valuable lignite deposits in the United States; industrial importance of deposits.

LOCOMOTIVE BOILERS

Repairing. Repairing Locomotives in a Contract Shop. Boiler Maker, vol. 23, no. 9, Sept. 1923, pp. 245–249, 7 figs. Description of contract locomotive repair shop that was built up around a war-time ordnance plant; types of boiler repairs handled and methods employed.

LOCOMOTIVES

Average Life. A Mortality Table for the Steam Locomotive, F. H. Adams. Ry. Rev., vol. 73, no. 12, Sept. 22, 1923, pp. 423–424. Interstate Commerce Commission bureau of valuation finds that average expected life for 8165 locomotives is about 31 years.

Carbon-Vanadium Steel for Reducing Weight. A Practical Example of Carbon-Vanadium Steel Use, R. J. Finch. Ry. Rev., vol. 73, no. 15, Oct. 13, 1923, pp. 532–534, 2 figs. Dynamic augment and weight of new Chicago & Northwestern Ry. Pacific-type locomotive reduced.

Consolidation. Consolidation Locomotive for the Polish State Railways, H. Dabrowski. Ry. Mech. Engr., vol. 97, no. 9, Sept. 1923, p. 623. Details of Consolidation or 2–8–0 type for handling freight traffic.

Design. Modern Locomotive Engine Design and Construction. Ry. Engr., vol. 44, nos. 522 and 524, July and Sept. 1923, pp. 269–275, and 334–339 and 350, 21 figs. July: Positive location of plates and buckle for laminated-type spring, determination of stresses in plate springs and buckles; application of load to laminated-type springs; adjustment of weight on springs; load-compensating arrangements. Sept.: Laminated springs; spring-compensating gear; design of coiled springs.

Feedwater Treatment. Treatment of Feed Water for Locomotive Use, and Result. Ry. & Locomotive Eng., vol. 36, no. 10, Oct. 1923, pp. 310 314. Report of committee to Traveling Engrs.' Assn.

Fireless. Fireless Locomotives. Eng. Progress, vol. 4, no. 7, July 1923, pp. 157–160, 12 figs. Design and operation; efficiency; advantages; field of utilization.

Heat Economy in. Heat Economy in Steam Locomotives, L. Schneider. Eng. Progress, vol. 4, no. 7, July 1923, pp. 139–144, 10 figs. Economy in design of furnace, boiler, preheaters, superheaters, engine and valve gear.

Internal-Combustion. High Power Internal Combustion Locomotives, J. S. Tritton. Ry. Rev., vol. 73, no. 14, Oct. 6, 1923, pp. 497–499, 4 figs. Also Ry. Engr., vol. 44, no. 524, Sept. 1923, pp. 325–327 and (discussion) 327–328, 4 figs. Transmission presents principal problem of adopting internal-combustion engines to locomotive service.

Lentz. The Lentz Valve as a Factor in Locomotive Design, Desider Ledacs Kiss. Ry. Rev., vol. 73, nos. 7 and 8, Aug. 18 and 25, 1923, pp. 225 233 and 269–275, 22 figs. Design and use of lift valves on European locomotives.

Mikado. Mikado Type Locomotives for Duluth & Iron Range. Ry. Jl., vol. 29, no. 9, Sept. 1923, p. 16, 1 fig. Equipped with feedwater heater and booster; with aid of latter tractive force is increased to 70,000 lb.; booster is piped to use superheated steam.

Mixed-Service. Locomotives for Mixed Service, G. Reder. Eng. Progress, vol. 4, no. 7, July 1923, pp. 151–154, 4 figs. Describes recent types of locomotives which may be used for greatest possible number of different types of trains.

Thermic Siphons. A Dynamometer Car Test on the N. C. & St. L. Ry. Ry. Rev., vol. 73, no. 15, Oct. 13, 1923, pp. 521–526, 7 figs. Value of thermic siphon determined in test of same locomotive with or without this device. See also Ry. Mech. Engr., vol. 97, no. 9, Sept. 1923, pp. 521–526, 7 figs.

Turbo-Electric Condensing. Ramsay Turbo-Electric Condensing Locomotive. Ry. Age, vol. 75, no. 15, Oct. 13, 1923, pp. 667–668, 3 figs. Experimental locomotive under development in England; results of tests.

The Ramsay Turbo-Electric Condensing Locomotive. Ry. Gaz., vol. 39, no. 12, Sept. 21, 1923, pp. 362–366, 6 figs. Further details of this locomotive and results of trials.

Valve Gears. Setting Valve Gears of the Radial Type, S. P. Kennedy. Ry. Mech. Engr., vol. 97, no. 10, Oct. 1923, pp. 701–704, 7 figs. Rapid method of setting and adjusting radial valve gears without rolling wheels.

Valve Control for Locomotives, H. Dubbel. Eng. Progress, vol. 4, no. 7, July 1923, pp. 149–151, 8 figs. Describes type which proved advantageous not only from standpoint of railway service, but also from that of heat economy and technique of manufacture.

LUBRICATING OILS

Properties. Lubricating Oils (Les huiles industrielles de graissage), J. Lévy. Technique Moderne, vol. 15, no. 17, Sept. 1, 1923, pp. 522–530, 6 figs. Properties desired in liquid lubricants; animal and vegetable oils and fats; distillation; cracking; fractionation in refining of oil.

Re-refining. A New Lubrication Development, David W. Dickie. Pac. Mar. Rev., vol. 20, no. 9, Sept. 1923, pp. 451–452. Describes process of refining discarded lubricating oil and recovering good lubricant contained therein.

Steam-Engine Cylinders. What Oil for Steam Engines?, Forrest A. Hoff. Oil News, vol. 11, no. 16, Aug. 20, 1923, pp. 28–29. Suggestions for compounding right oils for steam cylinders; type of feed, steam temperature and dryness important; formulas for cylinder oil.

Turbine. Deterioration of Turbine Oils in Use, Alexander Duckham and Stanley E. Bowrey. Engineering, vol. 116, no. 3012, Sept. 21, 1923, p. 353, 1 fig. Discusses deterioration due to atmospheric action on warm oils as principal cause of emulsification, and other circumstances contributing ill effects.

LUBRICATION

Boundary. The Nature of Lubrication in Engineering Practice, T. E. Stanton. Instn. Petroleum Technologists—Jl., vol. 9, no. 38, Aug. 1923, pp. 260–273, 4 figs. Results of pendulum experiments show that by means of comparatively simple apparatus characteristics of lubricants and bearing metals under conditions of boundary lubrication can be investigated rapidly and conveniently.

Pressure Lubricator. The "Ref" Pressure Lubricator. Engineering, vol. 116, no. 3014, Oct. 5, 1923, p. 426, 14 figs. Mechanical lubricator of German design suitable for use on marine steam engines, locomotives, internal-combustion engines, compressors, etc., chief feature of which is that any number of points up to 12 or more can be supplied with oil.

M

MACHINE DESIGN

Beauty in. Is Beauty an Important Factor in Machine Design?, K. H. Condit. Am. Mach., vol. 59, no. 13, Sept. 27, 1923, pp. 461–462, 1 fig. Views of Maxfield Parrish, artist, machinist and draftsman, who maintains that there is close relationship between artist and what he calls creative machinist.

MACHINE SHOPS

Skoda Works, Czechoslovakia. Skoda and the Revolution of Pilsen, Henry Obermeyer and Arthur L. Greene. Am. Mach., vol. 59, no. 14, Oct. 4, 1923, pp. 519–524, 8 figs. Cause for change in products produced; activity in railway and locomotive equipment; Skoda's resources; conditions regarding labor, coal and raw material.

MACHINE TOOLS

Paper Machinery. Special Tools for Making Paper-Mill Machinery, E. T. Spidy. Am. Mach., vol.

Manufactured by Advertisers — CLASSIFIED LIST OF MECHANICAL EQUIPMENT — Alphabetical List on page 166

Pulleys, Friction Clutch
* Allis-Chlamers Mfg. Co.
* Brown, A. & F. Co.
* Falls Clutch & Machinery Co.
Johnson, Carlyle Machine Co.
* Jones, W.A. Fdry. & Mach. Co.
Link-Belt Co.
* Medart Co.
* Wood's, T. B. Sons Co.

Pulleys, Iron
* Brown, A. & F. Co.
Chain Belt Co.
* Falls Clutch & Machinery Co.
* Gifford-Wood Co.
* Jones, W. A. Fdry. & Mach. Co.
Link-Belt Co.
* Medart Co.
* Wood's, T. B. Sons Co.

Pulleys, Paper
Rockwood Mfg. Co.

Pulleys, Steel
* Medart Co.

Pulleys, Wood
* Medart Co.

Pulling Tables (For Annealing Furnaces)
* Kenworthy, Chas. F. (Inc.)

Pulverizers
* Brown, A. & F. Co.
* Fuller-Lehigh Co.
* Smidth, F. L. & Co.

Pump Governors, Valves, etc.
(See Governors, Valves, etc. Pump)

Pumping Engines
(See Engines, Pumping)

Pumping Systems, Air Lift
* Ingersoll-Rand Co.

Pumps, Acid
Buffalo Steam Pump Co.
* Ingersoll-Rand Co.
* Nordberg Mfg. Co.
Taber Pump Co.
* Titusville Iron Works Co.

Pumps, Air
* Goulds Mfg. Co.
* Ingersoll-Rand Co.
* Westinghouse Electric & Mfg. Co.
* Wheeler, C. H. Mfg. Co.

Pumps, Ammonia
Buffalo Steam Pump Co.
* Goulds Mfg. Co.
* Ingersoll-Rand Co.
* Vogt, Henry Machine Co.
* Worthington Pump & Machinery Corp'n

Pumps, Boiler Feed
* Allis-Chalmers Mfg. Co.
Buffalo Steam Pump Co.
* Coppus Engineering Corp'n
* De Laval Steam Turbine Co.
* Goulds Mfg. Co.
* Ingersoll-Rand Co.
* Kerr Turbine Co.
* Wheeler, C. H. Mfg. Co.
* Worthington Pump & Machinery Corp'n

Pumps, Centrifugal
* Allis-Chalmers Mfg. Co.
Buffalo Steam Pump Co.
* Cramp, Wm. & Sons Ship & Engine Bldg. Co.
* De Laval Steam Turbine Co.
* Goulds Mfg. Co.
* Ingersoll-Rand Co.
* Kerr Turbine Co.
Lammert & Mann Co.
* Morris Machine Works
* Nordberg Mfg. Co.
Taber Pump Co.
* Westinghouse Electric & Mfg. Co.
* Wheeler, C. H. Mfg. Co.
* Wheeler Cond. & Engrg. Co.
* Worthington Pump & Machinery Corp'n

Pumps, Condensation
Buffalo Steam Pump Co.
* Ingersoll-Rand Co.
* Wheeler, C. H. Mfg. Co.

Pumps, Deep Well
* Allis-Chalmers Mfg. Co.
* Goulds Mfg. Co.
* Ingersoll-Rand Co.
Luitwieler Pumping Engine Co.
* Morris Machine Works
* Worthington Pump & Machinery Corp'n

Pumps, Dredging
* Ingersoll-Rand Co.
* Morris Machine Works
* Worthington Pump & Machinery Corp'n

Pumps, Electric
* Allis-Chalmers Mfg. Co.
Buffalo Steam Pump Co.
* Goulds Mfg. Co.
* Ingersoll-Rand Co.
Luitwieler Pumping Engine Co.
* Morris Machine Works
* Nordberg Mfg. Co.
Taber Pump Co.
* Worthington Pump & Machinery Corp'n

Pumps, Elevator
Buffalo Steam Pump Co.
* Goulds Mfg. Co.
* Worthington Pump & Machinery Corp'n

Pumps, Filter Press
Buffalo Steam Pump Co.
* Goulds Mfg. Co.

Pumps, Hand
* Goulds Mfg. Co.
Taber Pump Co.

Pumps, Hydraulic
* American Fluid Motors Co.

Pumps, Hydraulic Pressure
Buffalo Steam Pump Co.
* Goulds Mfg. Co.
* Ingersoll-Rand Co.
* Morris Machine Works
* Worthington Pump & Machinery Corp'n

Pumps, Lift and Force
Luitwieler Pumping Engine Co.

Pumps, Measuring
Wayne Tank & Pump Co.

Pumps, Measuring (Gasoline or Oil)
* Bowser, S. F. & Co. (Inc.)

Pumps, Mine
Luitwieler Pumping Engine Co.

Pumps, Oil
* Bowser, S. F. & Co. (Inc.)
Buffalo Steam Pump Co.
* Goulds Mfg. Co.
* Ingersoll-Rand Co.
Lunkenheimer Co.
Nugent, Wm. W. & Co. (Inc.)
Taber Pump Co.
* Worthington Pump & Machinery Corp'n

Pumps, Oil, Force-Feed
* Bowser, S. F. & Co. (Inc.)
* Goulds Mfg. Co.
Lunkenheimer Co.

Pumps, Oil (Hand)
* Bowser, S. F. & Co. (Inc.)
* Goulds Mfg. Co.
Lunkenheimer Co.
Nugent, Wm. W. & Co. (Inc.)

Pumps, Pneumatic Pressure
Luitwieler Pumping Engine Co.

Pumps, Power
* Allis-Chalmers Mfg. Co.
Buffalo Steam Pump Co.
* Goulds Mfg. Co.
* Ingersoll-Rand Co.
Luitwieler Pumping Engine Co.
* Nordberg Mfg. Co.
* Wheeler Cond. & Engrg. Co.
* Worthington Pump & Machinery Corp'n

Pumps, Rotary
* Goulds Mfg. Co.
Lammert & Mann Co.
Taber Pump Co.

Pumps, Steam
* Allis-Chalmers Mfg. Co.
Buffalo Steam Pump Co.
* Ingersoll-Rand Co.
* Nordberg Mfg. Co.
* Wheeler, C. H. Mfg. Co.
* Wheeler Cond. & Engrg. Co.
* Worthington Pump & Machinery Corp'n

Pumps, Sugar House
* Allis-Chalmers Mfg. Co.
Buffalo Steam Pump Co.
* Goulds Mfg. Co.
* Ingersoll-Rand Co.
* Worthington Pump & Machinery Corp'n

Pumps, Sump
Buffalo Steam Pump Co.
* Goulds Mfg. Co.
* Ingersoll-Rand Co.
* Morris Machine Works
* Smidth, F. L. & Co.
Taber Pump Co.

Pumps, Tank
Buffalo Steam Pump Co.
* Goulds Mfg. Co.
* Ingersoll-Rand Co.
Luitwieler Pumping Engine Co.
Taber Pump Co.
* Wheeler, C. H. Mfg. Co.
* Wheeler Cond. & Engrg. Co.
* Worthington Pump & Machinery Corp'n

Pumps, Turbine
* Allis-Chalmers Mfg. Co.
Buffalo Steam Pump Co.
* De Laval Steam Turbine Co.
* General Electric Co.
* Goulds Mfg. Co.
* Ingersoll-Rand Co.
* Kerr Turbine Co.
* Morris Machine Works
* Westinghouse Electric & Mfg. Co.
* Worthington Pump & Machinery Corp'n

Pumps, Vacuum
Buffalo Steam Pump Co.
* Croll-Reynolds Engrg. Co. (Inc.)
* Goulds Mfg. Co.
* Ingersoll-Rand Co.
Lammert & Mann Co.
* Nordberg Mfg. Co.
* Wheeler, C. H. Mfg. Co.
* Wheeler Cond. & Engrg. Co.
* Worthington Pump & Machinery Corp'n

Punches, Multiple
* Long & Allstatter Co.
Mackintosh-Hemphill Co.

Punches, Power
* Niagara Machine & Tool Works
* Royersford Fdry. & Mach. Co.

Punches and Dies
* Royersford Fdry. & Mach. Co.

Punching and Coping Machines
* Long & Allstatter Co.

Punching and Shearing Machines
* Long & Allstatter Co.
* Royersford Fdry. & Mach. Co.

Purifiers, Ammonia
* Frick Co. (Inc.)

Purifiers, Oil
* Bowser, S. F. & Co. (Inc.)
Elliott Co.
Nugent, Wm. W. & Co. (Inc.)

Purifying and Softening Systems Water
International Filter Co.
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Pyrometers, Electric
* American Schaeffer & Budenberg Corp'n
* Bristol Co.
* Crosby Steam Gage & Valve Co.
Engelhard, Chas. (Inc.)
* Superheater Co.
* Taylor Instrument Cos.

Pyrometers, Expansion Stem
* Tagliabue, C. J. Mfg. Co.

Pyrometers, Optical
* Taylor Instrument Cos.

Pyrometers, Pneumatic
* Uehling Instrument Co.

Pyrometers, Radiation
* Taylor Instrument Cos.

Racks, Machine, Cut
* James, D. O. Mfg. Co.
* Jones, W. A. Fdry. & Mach. Co.

Racks, Storage, Metal
Manufacturing Equipment & Engrg. Co.

Radiators, Steam and Water
* American Radiator Co.
* Smith, H. B. Co.

Railways, Industrial
Link-Belt Co.

Rams, Hydraulic
* Goulds Mfg. Co.
* Worthington Pump & Machinery Corp'n

Receivers, Air
* Brownell Co.
* Ingersoll-Rand Co.
* Scaife, Wm. B. & Sons Co.
* Walsh & Weidner Boiler Co.
* Wheeler Cond. & Engrg. Co.
* Worthington Pump & Machinery Corp'n

Receivers, Ammonia
* Frick Co. (Inc.)

Recorders, CO
* Tagliabue, C. J. Mfg. Co.
* Uehling Instrument Co.

Recorders, CO_2
* Tagliabue, C. J. Mfg. Co.
* Uehling Instrument Co.

Recorders, SO_2
* Tagliabue, C. J. Mfg. Co.
* Uehling Instrument Co.

Recording Instruments
(See Instruments, Recording)

Reducing Motions
* Crosby Steam Gage & Valve Co.

Refractories
* Drake Non-Clinkering Furnace Block Co.
Keystone Refractories Co.
* King Refractories Co. (Inc.)

Refrigerating Machinery
* De La Vergne Machine Co.
* Frick Co. (Inc.)
* Ingersoll-Rand Co.
Johns-Manville (Inc.)
* Nordberg Mfg. Co.
* Vilter Mfg. Co.
* Vogt, Henry Machine Co.
* Westinghouse Electric & Mfg. Co.

Regulators, Blower
* Davis, G. M. Regulator Co.
* Mason Regulator Co.

Regulators, Condensation
* Tagliabue, C. J. Mfg. Co.

Regulators, Damper
* Coppus Engineering Corp'n.
* Davis, G. M. Regulator Co.
* Fulton Co.
* Kieley & Mueller (Inc.)
* Mason Regulator Co.

Regulators, Electric
* General Electric Co.
* Westinghouse Electric & Mfg. Co.

Regulators, Feed Water
* Edward Valve & Mfg. Co.
Elliott Co.
* Kieley & Mueller (Inc.)

Regulators, Flow (Steam)
* Davis, G. M. Regulator Co.
* Schutte & Koerting Co.

Regulators, Humidity
* Fulton Co.
* Tagliabue, C. J. Mfg. Co.

Regulators, Hydraulic Pressure
* Mason Regulator Co.

Regulators, Liquid Level
* Tagliabue, C. J. Mfg. Co.

Regulators, Pressure
* Davis, G. M. Regulator Co.
* Edward Valve & Mfg. Co.
Engelhard, Chas. (Inc.)
* Fulton Co.
* General Electric Co.
* Kieley & Mueller (Inc.)
* Mason Regulator Co.
* Tagliabue, C. J. Mfg. Co.
* Taylor Instrument Cos.

Regulators, Pump
(See Governors, Pump)

Regulators, Temperature
* Bristol Co.
Engelhard, Chas. (Inc.)
* Fulton Co.
* Kieley & Mueller (Inc.)
* Sarco Co. (Inc.)
* Tagliabue, C. J. Mfg. Co.
* Taylor Instrument Cos.

Regulators, Time
* Tagliabue, C. J. Mfg. Co.

Reservoirs, Aerating
* Spray Engineering Co.

Resistance Material (Electrical)
Driver-Harris Co.

Revolution Counters
(See Counters, Revolution)

Rivet Heaters, Electric
* General Electric Co.

Riveters, Hydraulic
Mackintosh-Hemphill Co.

Riveters, Pneumatic
* Ingersoll-Rand Co.

Riveting Machines
* Long & Allstatter Co.

Roller Bearings
(See Bearings, Roller)

Rolling Mill Machinery
Mackintosh-Hemphill Co.
Treadwell Engineering Co.

Rolls, Bending
* Niagara Machine & Tool Works

Rolls, Crushing
Link-Belt Co.
* Worthington Pump & Machinery Corp'n

Rolls, Rubber
* Goodrich, B. F. Rubber Co.
* United States Rubber Co.

Rolls, Steel
Mackintosh-Hemphill Co

Roofing
Johns-Manville (Inc.)
Texas Co.

Roofing, Asbestos
Johns-Manville (Inc.)

Rope, Hoisting
Clyde Iron Works Sales Co.
* Roebling's, John A. Sons Co.

Rope, Transmission
Link-Belt Co.
* Roebling's, John A. Sons Co.

Rope, Wire
Clyde, Iron Works Sales Co.
* Roebling's, John A. Sons Co.

*Catalogue data of firms marked * appear in the A.S.M.E. Condensed Catalogues of Mechanical Equipment, 1923-24 Volume*

59, no. 16, Oct. 18, 1923, pp. 575–578, 11 figs. Machines and methods used by Dominion Engineering Works; turning, boring and grinding large cylinders and rolls of various materials.

Railway-Wheel Production. Machine Tools for Railway Wheel Production. Machy. (Lond.), vol. 22, no. 570, Aug. 30, 1923, pp. 685–691, 12 figs. Duplex boring mills by Webster & Bennett, Ltd., Coventry.

MACHINING METHODS

Curves, Large Radius. The Machining of Curves of Large Radius, E. W. Eager. Mech. World, vol. 74, nos. 1910 and 1912, Aug. 10 and 24, 1923, pp. 78 and 110–111, 5 figs. Methods and instruments for producing work, gages, or templets which have arcs or curves in their form.

MAGNESIUM ALLOYS

Properties. Magnesium and Extra-Light Alloys (Le magnésium et les alliages ultra-légers), Albert Portevin. Société des Ingénieurs Civils de France—Mémoires et Compte Rendu des Travaux, vol. 76, no. 4–5, Apr.-May 1923, pp. 486–507, 9 figs. partly on supp. plates. Mechanical properties of magnesium and effect of addition of other metals; effect of extrusion on mechanical properties; producers of magnesium alloys and analyses of their products; advantages and uses of extra-light alloys.

MALLEABLE CASTINGS

Structure. Malleable Castings and Their Changes at High Temperature (Sur la constitution des Fontes Malléables et les modifications qu'elles subissent instantanément aux hautes températures). Fonderie Moderne, vol. 17, Aug. 1923, pp. 274–276, 5 figs. Compares American and European malleable castings and their micro-structure (Revue de la Soudure autogène).

MATERIALS

Cohesive Force. Cohesion from the Engineering Standpoint, A. A. Griffith. Engineering, vol. 116, no. 3012, Sept. 21, 1923, p. 377. Explains author's theory of plastic strain, in which conclusion is reached that it is simply external manifestation of phase changes occurring within material. Paper before Brit. Assn.

Strength Testing. Further Researches on the Strength of Materials, W. E. Dalby. Roy. Soc.—Proc., vol. 103, no. A720, Apr. 3, 1923, pp. 8–25, 7 figs. Describes recent researches with author's modified testing machine and elastic recorder, and his new instrument for getting records of torque and twist between positive and negative limits, called elastic torque twist recorder.

The Testing of Materials and Its Effect on Engineering, G. B. Upton. Soc. Automotive Engrs.—Jl., vol. 13, no. 4, Oct. 1923, pp. 296–299 and (discussion) 299–300 and 312. Properties of materials; endurance curves; factor of safety. Discusses the four bases of design, namely strength, fatigue, stiffness, and shock.

METALLOGRAPHY

A. S. T. M. Report. Report of Committee E-4 on Metallography. Am. Soc. Testing Matls.—advance paper, no. 18, for meeting June 25–29, 1923, 15 pp. Proposed tentative definitions of terms relating to metallography; photography as applied to metallography; and metallographic testing of non-ferrous metals and alloys.

Structure, Theory of. Development and Possible Achievements of Metallographic Research (Entwicklung und mögliche Ziele der metallkundlichen Forschung), F. Sauerwald. Zeit. für Metallkunde, vol. 15, no. 7, July 1923, pp. 184–190. With special consideration of kinetic theory of structure.

METALS

Cutting Resistance of. The Significance of Tool Temperatures as a Function of the Cutting Resistance of Metals, H. A. Schwartz and W. W. Flagle. Am. Soc. Testing Matls.—advance paper, no. 21, for meeting June 25–29, 1923, 14 pp., 7 figs. Describes instrument for recording changes of temperature of drill or other cutting tool in action; gives data covering typical ferrous alloys of commerce; relations between energy per cu. in. of metal removed; temperature, and rate of removal of metal suggests utility of pyrometer in place of tool dynamometer.

Fatigue of. The Fatigue Failure of Metals, C. F. Jenkin. Roy. Soc.—Proc., vol. 103, no. A720, Apr. 3, 1923, pp. 121–138, 13 figs. Describes theory which appears to offer reasonable explanation of most of principal phenomena observed when wrought iron, steel, nickel, copper and some other metals are tested.

Gases in. Gases in Metals, Louis Jordan. Am. Soc. Testing Matls.—advance paper, no. 20, for meeting June 25–29, 1923, 16 pp. Methods for determining gases in metals; effects of gases in practical metallurgy; application of methods of analysis for gases.

Rustproof. Acid and Rust Proof Materials for Chemical Works, Rex Furness. Chem. Age, (Lond.), vol. 9, no. 219, Aug. 25, 1923, pp. 198–200. Describes more important acid-resisting and rustproof metals and alloys and discusses chemical properties which are demanded.

MOLDING MACHINES

Flask Equipment. Suitable Flask Equipment for Molding Machine, Arnold Lenz. Can. Foundryman, vol. 14, no. 9, Sept. 1923, pp. 13–16 and 32, 19 figs. Laying out of flasks; materials for flasks; equipment should be interchangeable; no gaggers need be used, if properly fitted to pattern; sand strip, which is really a permanent continuous gagger, recommended.

MOLDING METHODS

Planer Tables. How to Mold a Planer Table, R. H. Palmer. Foundry, vol 51, no. 19, Oct. 1, 1923, pp. 767–769, 8 figs. Method of preparing and venting sand bed to prevent scabbing on face; faults of omission and commission in patternmaking practice.

MOLDS

Design. Design of Cast-Iron Molds for Casting under Pressure (Le Dessin des Coquilles pour le Moulage sous pression). Fonderie Moderne, vol. 17, Aug. 1923, pp. 256–258, 1 fig. Difficulties in casting, elimination of air, complete filling of mold, life of mold of various compositions. (Abstract from La Machine Moderne.)

Gating. The Importance of Proper Gating, F. C. Edwards. Metal Industry (Lond.), vol. 23, no. 10, Sept. 7, 1923, pp. 195–196, 3 figs. Discusses factors which should be considered.

MOTOR BUSES

Design. New Yellow Coach Bus Chassis has 4-Wheel Brakes. Motor Trans. (N. Y.), vol. 29, no. 3, Sept. 1, 1923, pp. 92–97, 11 figs. Built for general use throughout the country and will accommodate single or double-deck bodies; 4-cylinder 4 by 6 Knight engine used.

Suspension. Automobile Suspension (Contribution à l'étude de la suspension automobile), M. Friquet. Industrie des Tramways, vol. 17, no. 200, Aug. 1923, pp. 269–275, 8 figs. Design of suspensions of Paris omnibuses; develops simple theory for construction of a suspension having variable flexibility; describes types of suspensions studied and results obtained.

MOTOR-TRUCK TRANSPORTATION

Cost. What Determines the Cost of Truck Haulage? Contract Rec. & Eng. Rev., vol. 37, no. 38, Sept. 19, 1923, pp. 898–900. Items which are often overlooked in figuring true cost of motor-truck transportation; selecting cost unit.

MOTOR TRUCKS

German. A New German Lorry. Motor Transport (Lond.), vol. 37, no. 967, Sept. 10, 1923, pp. 323–324, 3 figs. Front-wheel-driven three tonner with hydraulically controlled transmission to be exhibited at Berlin Show.

Six-Wheel Conversion Set. A Six-Wheel Conversion. Motor Transport (Lond.), vol. 37, no. 967, Sept. 10, 1923, pp. 327–328, 5 figs. Danish invention for increasing carrying capacity of small or large vehicles.

Steam. Foden's Bring Out a Six-Wheeler. Motor Transport (Lond.), vol. 37, no. 969, Sept. 24, 1923, pp. 375–377, 6 figs. Details of new truck developed by Foden Works at Sandbach, Eng., specially designed for turning in confined spaces and with numerous other original features; tractive unit fully 12 tons; compound engine supplied with steam at 220 lb. per sq. in. boiler pressure from locomotive-type boiler.

MOTORCYCLES

Engines. The Columbus Light Motorcycle Engine (Der "Columbus" Leichtkraftrad-Motor), G. Reinhard. Motorwagen, vol. 26, no. 20, July 31, pp. 329–331, 5 figs. A one-cylinder four-stroke engine weighing 8 5 kg.

N

NOMENCLATURE

A.S.T.M. Committee Report. Report of Committee E-8 on Nomenclature and Definitions. Am. Soc. for Testing Matls.—advance paper, no. 5, for meeting June 25–29, 1923, 16 pp.

NON-FERROUS METALS

A.S.T.M. Report. Report of Committee B-2 on Non-Ferrous Metals and Alloys. Am. Soc. Testing Matls.—advance paper, no. 15, for meeting June 25–29, 16 pp., 1 fig. Proposed revised tentative specifications for seamless admiralty condenser tubes and ferrule stock; and for determination of zinc in pig lead.

Electrolytic Production. Metallurgy of Electrolytic Non-Ferrous Metals (Métallurgie des métaux non ferreux par l'électrolyse), M. Altmayer. Société des Ingénieurs Civils de France—Mémoires et Compte Rendu des Travaux, vol. 76, no. 4–5, Apr.-May 1923, pp. 508–542, 7 figs. partly on supp. plate. Discusses copper, lead, tin, zinc, cadmium, nickel and precious metals, and describes principally American practice of electrolytic production.

Research Problems. The Trend of Research in the Non-ferrous Industry, Paul D. Merica. Indus. & Eng. Chem., vol. 15, no. 9, Sept. 1923, pp. 895–897. Corrosion problem; what is to be done with scrap; chemistry of metals at high temperature; new industrial uses for non-ferrous metals and alloys; fabrication of metals and alloys.

O

OIL ENGINES

Continental Practice. Continental Oil Engine Practice, J. L. Chaloner. Gas & Oil Power, vol. 19, no. 217, Oct. 4, 1923, pp. 1–3. Professor Nägel's researches; port scavenging; M. A. N. and Sulzer systems; cooling; preheating of starting air; Professor Neumann's tests; mechanical injection; beat transmission.

Marine, British. New British Marine Oil Engines Developed. Mar. Eng., vol. 28, no. 9, Sept. 1923, pp. 566–568, 3 figs. Beardmore builds largest semi-Diesel ever installed in cargo vessel with 750 b. hp.; Richardsons, Westgarth & Co. modify Tosi engine.

Piston and Cylinder Lubrication. Operation of Marine Oil Engines, John Lamb. Inst. Mar. Engrs.—Trans., session 1923–1924, Aug. 1923, pp. 172–192 and (discussion) 192–205, 4 figs. Discusses lubrication of cylinders and pistons.

OIL FUEL

Burners. The Scarab-Coen Oil Burning System. Oil Eng. & Finance, vol. 4, no. 85, Aug. 25, 1923, pp. 212–214, 3 figs. System of mechanical oil burning which operates under low pressure; details of design; oil heater; duplex strainer.

Combustion in Diesel Engines. Liquid Fuels and Their Combustion in Diesel Engines (Flüssige Brennstoffe und ihre Verbrennung in der Deiselmaschine), Otto Alt. Zeit. des Vereines deutscher Ingenieure, vol. 67, no. 28, July 14, 1923, pp. 686–691, 13 figs. Review of knowledge on chemical and physical properties of fuels and of combustion process in Diesel engine; gives tables showing ignition temperatures required in engine for various fuels; apparently no gasification and no appreciable evaporation precede ignition; ignition point depends upon chemical constitution; all liquid fuels, including benzol, burn when the required ingition temperatures are reached.

Efficient Burning. Burning Liquid Fuel Efficiently, H. A. Anderson. Iron Trade Rev., vol. 73, no. 16, Oct. 18, 1923, pp. 1097–1098 and 1105. Type of burner and design of furnace principal factors in economical use of fuel oil; refractories, use of insulating brick, and condition of fuel also influence efficiency

Industrial Power Plants. Oil as Fuel in Industrial Power Plant, Douglas Henderson. Power Plant Eng., vol. 27, no. 19, Oct. 1, 1923, pp. 974–976, 2 figs. How practical and economic considerations affect use and selection of fuel.

OPEN-HEARTH FURNACES

Compressed-Gas Firing. Compressed-Gas Firing of Open-Hearth Furnaces, Gerhard Donner. Iron & Coal Trades Rev., vol. 107, no. 2897, Sept. 7, 1923, p. 335. 3 figs. Also Foundry Trade Jl., vol. 28, no. 371, Sept. 27, 1923, p. 273, 3 figs. Describes tests carried out, and results obtained, on experimental 3-ton open-hearth furnace heated by compressed gas. Translated from Stahl u. Eisen.

Hoesch Process. Open-Hearth Process at the Hoesch Works, Otto Schweitzer. Iron & Coal Trades Rev., vol. 107, no. 2895, Aug. 24, 1923, pp. 255–256, 3 figs. Report to Steel-Works Committee of German Iron & Steel Inst. Translated from Stahl u. Eisen.

Lime vs. Limestone Practice. Lime vs. Limestone in Basic Open-Hearth Practice as Affecting Time Costs, Lewis M. Fulton. Iron & Steel of Can., vol. 6, no. 9, Sept. 1923, pp. 180–181. Comparison of material costs.

ORDNANCE

Testing Ground for. Aberdeen Proving Ground, Fred B. Fletcher. Iron Trade Rev., vol. 73, no. 16, Oct. 18, 1923, pp. 1091–1096, 7 figs. Vast laboratory covering 36,000 acres established in Maryland by U. S. Government, where explosives, projectiles, armor plate, guns and gun carriages, artillery mounts and other items of ordnance are tested prior to acceptance.

OXY-ACETYLENE WELDING

Overhead. Welding Over-Head with the Oxy-Acetylene Flame, C. J. Nyquist. Am. Welding Soc.—Jl., vol. 2, no. 8, Aug. 1923, pp. 13–14. Discussion of one of most difficult applications of oxy-acetylene welding.

Sheet Aluminum. The Autogenous Welding of Sheet Aluminium by the Oxy-Acetylene Process, A. Eyles. Machy. (Lond.), vol. 22, no. 574, Sept. 27, 1923, pp. 822–825, 19 figs. Aluminum welding fluxes; welding material; preparing metal for welding; power of blowpipes; execution of sheet-aluminum welding; treatment after welding.

Tanks. Welding Small Tanks by the Oxy-Acetylene Process. Acetylene Jl., vol. 25, no. 3, Sept. 1923, pp. 117–124, 20 figs. Welding practices; examples of tank welding; comparison of costs.

P

PAINTING

Air Brush. Cost of Paint Versus Cost of Painting, Howard W. Beach. Compressed Air Mag., vol. 28, no. 9, Sept. 1923, pp 620–621, 4 figs. Use of modern air brush in painting cuts the total cost of the work in half.

PAINTS

Testing Films. Further Studies of the Physical Properties of Drying-Oil, Paint and Varnish Films, Harley A. Nelson and George W. Rundle. Am. Soc. Testing Matls., advance paper, no. 50, for meeting June 25–29, 1923, 13 pp., 6 figs. Discusses three aspects of testing of paint films.

PATTERNS

Large Castings. Large Pattern and Core Work on the Pacific Coast. Am. Mach., vol. 59, no. 15, Oct. 11, 1923, pp. 553–555, 7 figs. Method, used in making large pipe connections for turbine work, of building both patterns and cores with sand over skeleton

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CLASSIFIED LIST OF MECHANICAL EQUIPMENT

Alphabetical List on page 166

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(See Stacks, Steel)

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*Catalogue data of firms marked * appear in the A.S.M.E. Condensed Catalogues of Mechanical Equipment, 1923-24 Volume*

wooden frames to cheapen cost where but few castings are required.

Nickel-Plated Plates. Nickel Plated Production Pattern Plates, William H. Parry. Metal Industry (N. Y.), vol. 21, no. 9, Sept. 1923, p. 358. Method of overcoming difficulty of sand adherence.

Standardization. Pattern Standardization, E. S. Carman. Metal Industry (N. Y.), vol. 21, no. 10, Oct. 1923, pp. 400-401. Need for this work and possibilities of eliminating some of unseen wastes of foundry. (Abstract.) Bul. Am. Foundrymen's Assn.

PIGMENTS

White Paint, Optical Properties. Some Optical Properties of White Paint Pigments in the Ultra-Violet Spectrum, A. H. Pfund. Am. Soc. Testing Matls., advance paper, no. 51, for meeting June 25–29, 1923, 11 pp., 6 figs. Treats of certain properties of paint pigments in ultra-violet region of spectrum.

PIPE

Friction Losses. New Logarithmic Equation for Friction Losses in Pipes, F. W. Greve. Eng. News-Rec., vol. 91, no. 15, Oct. 11, 1923, p. 605. Formula devised with aid of reducing number of variables to minimum.

Reinforced, Stresses in. The Stresses in Pipes Reinforced by Steel Rings, Gilbert Cook. Engineering, vol. 116, no. 3015, Oct. 12, 1923, pp. 477–478, 2 figs. Investigation of conditions under which reinforced pipe may be made lighter than plain pipe even when no difficulties of welding would be encountered; conclusions regarding relation between spacing of rings and their effectiveness. Paper before Brit. Assn.

PLANERS

Herringbone-Gear. A New Herringbone Gear Planer, N. Leerberg. Am. Mach., vol. 59, no. 15, Oct. 11, 1923, pp. 561–563, 3 figs. Features of design proposed to overcome difficulties usually encountered; two tools cut simultaneously and move in helical path; work held stationary during cutting to give stability.

PLATES

Rectangular, Stresses in. Stress Distribution in a Rectangular Plate having two Opposing Edges Sheared in Opposite Directions, C. E. Inglis. Roy. Soc.—Proc., vol. 103, no. A723, July 2, 1923, pp. 598–610, 11 figs. Distributions obtained are apparently in close agreement with those experimentally determined by Prof. Coker.

PRESSES

Hydraulic. Hydraulic Plants: A Few General Considerations, H. S. Cattermole. Mech. World, vol. 74, no. 1914, Sept. 7, 1923, pp. 145–146. Hydraulic plants for forging, riveting, shearing, baling, and other pressing operations are grouped in four types, each of which is discussed.

PRESSWORK

Car-Shop. Car Shop Press Work, L. C. Morrow. Am. Mach., vol. 59, no. 16, Oct. 18, 1923, pp. 571–574, 8 figs. Production limitations; multiple-punching operations on large work; heating diaphragms in "continuous" furnace and pressing them in 450-ton high-speed crankpress; time-saving devices.

PULVERIZED COAL

British Practice. Foreign Developments in Firing Pulverized Fuel, C. H. S. Tupholme. Power Plant Eng., vol. 27, no. 20, Oct. 15, 1923, pp. 1033–1036, 7 figs. Discusses use of powdered fuel with particular reference to British practice.

Plate-Heating Furnaces. Powdered Fuel For Furnace Work. Engineering, vol. 116, no. 3014, Oct. 5, 1923, pp. 425–426, 5 figs. partly on p. 424. Details of pulverized-coal installation for plate-heating furnace.

PUMPS

Deep-Well. A New Type of Deep Well Pump. Refrigeration, vol. 32, no. 6, July 1923, pp. 42–43, 5 figs. Water elevated by means of propeller similar to that employed for propelling ships. Advantages of Axiflo pump.

PYROMETERS

Thermoelectric. Notes on Thermoelectric Pyrometers and Instructions for Their Use in Heat Treating Steel. Am. Soc. for Steel Treating—Trans., vol. 4, no. 3, Sept. 1923, pp. 410–430, 8 figs. Thermocouple or "fire-end"; leads from thermocouple to indicator or recorder; indicators and recorders; cold-junction compensation; installing pyrometers. Report of Sub-Committee—IV, on Pyrometry.

R

RAILS

Corrosion, Prevention of. Oiling Prevents Corrosion of Rail and Fixtures. Ry. Rev., vol. 73, no. 19, Sept. 15, 1923, pp. 377–378, 2 figs. Delaware Lackawanna & Western R. R. develops cheap and satisfactory way to prevent corrosion from salt drippings and other causes.

Manufacture. The Production of Iron and Steel for Railway Purposes, Cecil J. Allen. Ry. Engr., vol. 44, nos. 521, 523 and 524, June, Aug. and Sept., 1923, pp. 222–226, 309–313 and 344–349, 26 figs. Methods employed in manufacturing iron and steel constituents of railway track, structures and rolling stock. June: Rolling of steel rails and heavy sections. Aug.: Finishing, testing and inspection of steel rails. Sept.: Recent tests on basic open-hearth rails and method and results of Sandberg sorbitic treatment.

RAILWAY ELECTRIFICATION

Illinois Central, Chicago. Terminal Improvement and Electrification of the Illinois Central Railroad at Chicago, Daniel J. Brumley. Ry. Rev., vol. 73, no. 9, Sept. 1, 1923, pp. 299–303. Work now in progress involves extensive rearrangement of facilities in addition to change of motive power.

Melbourne, Australia. Suburban Electrification at Melbourne, Australia. Eng. News-Rec., vol. 91, no. 15, Oct. 11, 1923, pp. 600–602, 3 figs. Multiple-unit electric and steam main-line trains on same tracks of 145-mi., 1500-volt d. c. system completed in 1923; economic results; quicker service increases traffic and revenue.

RAILWAY MOTOR CARS

Diesel-Electric. Observations Made on the Use of Polar-Deva Diesel-Electric Motors on Swedish Railways (Constatations effectuées au cours d'un voyage d'études relatif à l'exploitation des chemins de fer à l'aide des automotrices Diesel-électriques Polar-Deva en usage en Suède), R. Jourdin. Revue Générale des Chemins de Fer, vol. 42, no. 3, Sept. 1923, pp. 187–202, 6 figs. Design, construction and operation of cars, including mechanical and electrical equipment, fuel consumption, cost data, etc.; looks upon Diesel-electric as a stepping-stone to complete electrification.

Electric. Motor Car and Trailer of the Stockholm Railway Company (Aktiebolaget Stockholms spårvagars nya motor-och släpvagnar), Gösta Lindman. Teknisk Tidskrift, vol. 53, no. 9, Mar. 3, 1923, pp. (Elektroteknik) 31–35, 9 figs. Details of design and construction of new rolling stock for overhead electric lines.

Gas-Electric-Battery. A Gas-Electric-Battery Car for Railway Service, R. J. Needham. Ry. Rev., vol. 73, no. 15, Oct. 13, 1923, pp. 535–539, 2 figs. Reserve capacity and provision against breakdowns combined with double-end control, regenerative braking and other special features.

Gasoline. Gasoline Motorized Coach for the C. & N. W. Ry. Age, vol. 75, no. 13, Sept. 29, 1923, pp. 585–587, 3 figs. Trial run shows practicability of synchronized double motor drive and double-end control.

Light Self-Propelled Gasoline Driven Motor Car. Ry. & Locomotive Eng., vol. 36, no. 10, Oct. 1923, pp. 305–306, 2 figs. Capacity for 41 passengers with baggage compartment.

Pneumatically Synchronized Engines. Two Pneumatically Synchronized Engines Used in New Railcar. Automotive Industries, vol. 49, no. 15, Oct. 11, 1923, pp. 749–751, 4 figs. Standard railway coach, adopted in preference to lighter automotive construction, requires more power than single stock unit will develop; clutches, gears and throttle controlled by air; brake compressor electrically driven.

Types. Railroad Motor Cars. Eng. Progress, vol. 4, no. 7, July 1923, pp. 125–128, 6 figs. Types; drive; power transmission; engine equipment.

RAILWAY OPERATION

Car Interchange. Interchange of Rolling Stock. Int. Ry. Congress—Bul., vol. 5, no. 8–9, Aug.-Sept. 1923, pp. 747–770. Discussion on interchange of freight cars and penalty charges in case of delay in return of that stock; rules to be adopted in relations between railways themselves; rules to be adopted in relations between railways and consignors and consignees.

Train Control. Automatic Train Control, W. J. Thorrowgood. Ry. Engr., vol. 44, no. 521, June 1923, pp. 128–220. Cost; comparative figures; need for automatic train control.

Automatic Train Control on Chicago & Alton R. R. Ry. Rev., vol. 73, no. 11, Sept. 15, 1923, pp. 379–384, 14 figs. Test section 14 mi. in length recently put in service between Normal and Lexington, Ill.

I. C. C. Report on Sprague Train-Control Tests on N. Y. C. Ry. Signaling, vol. 16, no. 9, Sept. 1923, pp. 367–369. Analysis of tests; it has been demonstrated that magnetic impulse can be transmitted in electrified territory from permanent track magnets to locomotive regardless of speed, oscillation, or weather conditions, and that such impulse will actuate locomotive apparatus to provide automatic brake application in practical manner. (Abstract.)

Train Control Device Tested by the Big Four. Ry. Elec. Engr., vol. 14, no. 9, Sept. 1923, pp. 269–272, 8 figs. Indiana Equipment Corp. demonstrates its apparatus in connection with freight-train service.

RAILWAY REPAIR SHOPS

Electrical Applications. Electrical Applications at the Transcona Shops, Alfred C. Turtle. Ry. Elec. Engr., vol. 18, no. 9, Sept. 1923, pp. 261–267, 17 figs. Canadian national railways make extensive use of electric energy; heat treatment with electric furnace.

Locomotive. A Straight Line Method for Locomotive Shops, Lawrence Richardson. Ry. Rev., vol. 73, no. 10, Sept. 8, 1923, pp. 339–345, 4 figs. Progressive system for classified repairs patterned after best industrial production practice.

Burlington Builds New Locomotive Shops. Ry. Age, vol. 75, no. 14, Oct. 6, 1923, pp. 611–615, 6 figs. Construction on new site of ample area at Denver affords opportunity for well-planned development.

RAILWAY SIGNALING

Automatic. Automatics on Paris Grande Ceinture, T. S. Lascelles. Ry. Signaling, vol. 16, no. 9, Sept. 1923, pp. 363–367, 12 figs. General types of French signals compared with new automatics.

The Automatic Signalling Between Marylebone and Wembley, Great Central Section, London & North Eastern Railway. Ry. Gaz., vol. 39, no. 10, Sept. 7, 1923, pp. 302–309, 16 figs. Describes new features and departures from precedent; how steam worked railway has all those safeguards and facilities hitherto only to be found on rapid-transit electrically operated lines.

Fog Repeater Signals. Signalling Apparatus on the Metropolitan Railway for Use in Foggy Weather and Snow, W. Challis. Ry. Engr., vol. 44, no. 522, July 1923, pp. 245–247, 7 figs. Describes fog repeater signals, which enable trains to run to time even in very dense fogs. (Abstract.)

Interlocking. Dynamic Indication for A. C. Power Interlockings. Ry. Engr., vol. 44, no. 521, June 1923, pp. 205–206 and 211, 3 figs. Describes how dynamic indication may be obtained for points and signals operated by alternating currents.

Train-Order and Interlocking. Train-Order Signals at Interlockers. Ry. Signaling, vol. 16, no. 9, Sept. 1923, pp. 360–362, 4 figs. Confusion eliminated by using interlocking signal as train-order signal.

RAILWAY TRACK

Crossings. An Analysis of the Various Methods Used for Calculating Dimensions for Points and Crossings, R. D. Walker. Ry. Engr., vol. 44, no. 523, Aug. 1923, pp. 314–315, 5 figs. Discusses four general methods, namely, (1) turnout curve tangential to main line and to crossing at theoretical point of crossing; (2) turnout curve tangential to switch at its heel and to crossing at theoretical point of crossing; (3) turnout curve tangential to main line and to wing rail of crossing at its toe; and (4) turnout curve tangential to switch at its heel and to wing rail of crossing at its toe.

Rail-Packing Machine. Machine for Packing the Rails. Eng. Progress, vol. 4, no. 7, July 1923, p. 145, 2 figs. Machine consists of air pump driven by 4-stroke combustion motor and of packing tool.

RAILWAY YARDS

Electric Switching Dummy. Accumulator Motor Truck with Capstan for Shunting Purposes. Eng. Progress, vol. 4, no. 8, Aug. 1923, p. 173, 4 figs. Describes small motor truck for shunting purposes on factory sidings, designed by Brown, Boveri & Co., Mannheim.

REDUCTION GEARS

Calculation. Calculation of High-Speed High-Power Gears (Calcul des engrenages à grande vitesse et pour grande puissance), Alb. Schlag. Revue Universelle des Mines, vol. 18, no. 5, Sept. 1, 1923, pp. 321–344, 10 figs. Gears for speed reduction, their calculation and construction, including dimensions of pinions; profile, types and angle of teeth; recommends 30-deg. angle.

REFRIGERANTS

Natural-Gas Gasoline as. The Use of Highly Volatile Natural Gas Gasoline as a Refrigerant, L. D. Wyant. U. S. Bur. of Mines—Reports of Investigations, no. 2510, Aug. 1923, 10 pp. Experiments indicate that volatile gasoline can be used to advantage in many refrigerating plants.

REFRIGERATION

Packing-House. Refrigeration in the Packing House, H. J. Macintire. Southern Engr., vol. 40, no. 1, Sept. 1923, pp. 39–41, 2 figs. Refrigeration required and temperatures used with various products.

RESEARCH

Iron Industry. Scientific Research in the Iron Industry (Wissenschaftliche Forschung in der Eisenindustrie), P. Goerens. Stahl u. Eisen, vol. 43, no. 37, Sept. 13, 1923, pp. 1191–1199, 10 figs. The relation of research to development of iron industry; its purpose, costs and benefits; the necessity of comprehensive industrial research, and coördination between industrial research bureaus, investigating committees, iron-research institutes and colleges. Editorial comment.

ROLLING MILLS

Drives. Adjustable Speed Main Roll Drives, A. K. Bushman. Gen. Elec. Rev., vol. 26, no. 10, Oct. 1923, pp. 681–687, 7 figs. Discusses advantages and disadvantages of various methods of obtaining adjustable speed control of main rolls used in manufacture of steel; compares relative merits of a.c. and d.c. systems.

Drives, Flywheels for. Flywheels for Steel Mill Drives, L. A. Umansky. Gen. Elec. Rev., vol. 26, no. 19, Oct. 1923, pp. 688–707, 21 figs. Considers character of rolling-mill load; energy of flywheels; characteristics of induction motors; effect on motor size; cost of operating flywheels; etc. Flywheel calculations.

Electric Control. The Electrical Control for a Hot Strip Mill, M. J. Wohlgemuth. Elec. Jl., vol. 20, no. 9, Sept. 1923, pp. 322–325, 9 figs. Describes control arrangements at plant of West Leechburg Steel Co.

Electrically Driven. Electric Drive of Reversing Mill, C. B. Huston. Elec. World, vol. 82, no. 12, Sept. 22, 1923, pp. 577–580, 7 figs. Third in same plant to be converted from steam drive; rolling requirements; special features embodied in main mill motor; provisions for starting reversing and regulating load.

"Motorizing" the 33-inch Structural Mill at the Homestead Steel Works, S. S. Wales. Gen. Elec. Rev., vol. 26, no. 10, Sept. 1923, pp. 662–668, 7 figs. Shows results obtained by substituting electric motor for steam engine.

Manufactured by Advertisers — CLASSIFIED LIST OF MECHANICAL EQUIPMENT — Alphabetical List on page 166

Thread Cutting Tools
* Crane Co.
* * Jones & Lamson Machine Co.
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* Link-Belt Co.

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* * American Machine & Foundry Co.

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* * Kenworthy, Chas. F. (Inc.)

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* * Warner & Swasey Co.

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Tools, Pneumatic
* * Ingersoll-Rand Co.

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* * Brown Hoisting Machinery Co.
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* Northern Engineering Wks.
* Reading Chain & Block Corp'n
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* Link-Belt Co.

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* Clyde Iron Works Sales Co.
* Lidgerwood Mfg. Co.
* * Roebling's, John A. Sons Co.

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* * Westinghouse Electric & Mfg Co

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Transmissions, Automobile
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* * Jenkins Bros.
* Johns-Manville (Inc.)
* * Kieley & Mueller (Inc.)
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Unloaders, Ballast
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Valves, Balanced
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* * Reading Steel Casting Co. (Inc.) (Pratt & Cady Division)
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Valves, Plug
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Valves, Pop Safety
* * American Schaeffer & Budenberg Corp'n
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* * Crane Co.
* * Crosby Steam Gage & Valve Co.
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Valves, Pump
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* Johns-Manville (Inc.)
* * Nordberg Mfg. Co.
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Valves, Radiator
* * American Radiator Co.
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Valves, Radiator, Packless
* * American Radiator Co.
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*Catalogue data of firms marked * appear in the A.S.M.E. Condensed Catalogues of Mechanical Equipment, 1923-24 Volume*

The Consett Iron Company. Iron & Coal Trades Rev., vol. 107, no. 2893, Aug. 10, 1923, p. 191, 2 figs. Details of new electrical rolling mills, consisting of 40-in. slabbing mill, 42-in. plate mill, 32-in. light plate mill, and chequer-plate mill.

Plate. New Plate Mill at Blochairn Works, Glasgow. Iron & Coal Trades Rev., vol. 107, no. 2899, Sept. 21, 1923, pp. 435-437, 5 figs. New mill consists of two stands of 8-ft. by 32-in. rolls, driven by three-crank reversing engine.

Strip Steel. Strip Requirements Are Exacting, R. H. Ingraham. Iron Trade Rev., vol. 73, no. 16, Oct. 18, 1923, pp. 1103-1105. Various steps in process of manufacturing hot and cold-rolled product; causes of and remedies for many defects; important factors.

S

SAND, MOLDING

Cohesiveness Testing. Sand Conservation and Reclamation Tests Using the Doty Cohesiveness Testing Machine, R. F. Harrington, W. L. MacComb and M. A. Hosmer. Foundry Trade Jl., vol. 28, no. 366, Aug. 23, 1923, pp. 153-156, 3 figs. Enumeration of inconsistencies which authors' investigations have indicated. Summary of results of tests. (Abstract.) Paper presented before Am. Foundrymen's Assn.

Permeability. Moulding Sand Permeability. Metal Industry (Lond.), vol. 23, no. 13, Sept. 28, 1923, pp. 268-269, 1 fig. Apparatus and method for testing permeability of molding sands due to joint committee of Am. Foundrymen's Assn. and Nat. Research Council on molding sand investigation.

Preparation and Handling. The Mechanical Handling and Preparation of Sands, H. M. Lane. Foundry Trade Jl., vol. 28, no. 370, Sept. 20, 1923, pp. 242-245, 9 figs. Preparation of both facing and backing sand; selection of new sand; equipment used for handling. Paper presented to Paris Foundry Congress.

Treatment. A Modern Sand Plant in Germany (Une sablerei moderne en Allemagne), L. and R. Bonnaud. Fondérie Moderne, vol. 17, Sept. 1923, pp. 302-309, 7 figs. Describes equipment and methods in automatic plant producing foundry sand; notes on French practice; preparation of sand.

SCREW THREADS

Standardization, Germany. Introduction of Thread Standardization in Germany (Die Durchführung der Gewindenormung in Deutschland), G. Schlesinger. Zeit. des Vereines deutscher Ingenieure, vol. 67, no. 25, June 23, 1923, pp. 749-754, 19 figs. Development of standards; Whitworth and metric unit thread standards; tolerances; templets.

SEAPLANES

Navy-Wright Racer. The Navy-Wright Racer for the Schneider Cup. Aviation, vol. 15, no. 13, Sept. 24, 1923, p. 365, 1 fig. Racing seaplane built by Wright Aeronautical Corp. has wing spread of 28 ft., height of 11 ft. $7^1/_4$ in., and length of 28 ft. $4^1/_4$ in.; on trial trip it averaged more than 180 mi. per hr. over $2^1/_2$-mi. course; equipped with high-compression 700-hp. 12-cycle Vee-type water-cooled engine.

SHEARS

Rotary Plate. Self-contained Hydraulic Tools. Machy. (Lond.), vol. 22, no. 574, Sept. 27, 1923, pp. 813-816, 7 figs. Rotary shearing machine for $^3/_8$-in. plates.

SOLDERING

Materials, Technology of. The Technology of Soldering Materials. Chem. Trade Jl. & Chem. Engr., vol. 73, no. 1891, Aug. 17, 1923, pp. 185-186. Review of modern progress.

STANDARDIZATION

Needs and Limitations. Standardization Is the Salvation of American Industry, Frank B. Gilbreth. Chem. Age (N. Y.), vol. 31, no. 9, Sept. 1923, pp. 385-386. Need of standardization; superstandardization; standardization in Europe; significance of standardization. See also article by Albert M. Whitney on Limitations on Standardization, pp. 387-388.

Soc. Automotive Engrs. Tentative Standardization Work. Soc. Automotive Engrs.—Jl., vol. 13, no. 4, Oct. 1923, pp. 339-343, 4 figs. Use of both bilateral and unilateral systems of expressing tolerances proposed; recommends adoption of standard brake test; revised molding standards proposed.

Trend of. The Trend of Standardization, George K. Burgess. Am. Soc. Testing Matls.—advance paper, no. 1, for meeting June 25-29, 1923, 10 pp. Discusses agencies at work in field of standardization, their inter-relations and what they are trying to accomplish; relation of research to standardization.

United States. Progress of Standardization in the United States, Warren R. Roberts. Min. Congress Jl., vol. 9, nos. 9 and 10, Sept. and Oct. 1923, pp. 322-325 and 362. List of organizations which are now and have been carrying on work along standardization lines; reports on standardization received by author from technical societies.

STEAM

Steam-Air Mixtures. A New Diagram for Steam-Air Mixtures (Ein neues Diagramm für Dampfluftgemische), R. Mollier. Zeit. des Vereines deutscher Ingenieure, vol. 67, no. 36, Sept. 8, 1923, pp. 869-872, 5 figs. Points out that in practical applications of steam-air mixtures the water vapor can always be treated as a complete gas; principle of calculation is then very simple; new diagram and its application to processes of drying and water recooling.

STEAM ACCUMULATORS

Principles and Types. The Importance of Different Types of Steam Accumulators in the Conservation of Power (Die Bedeutung verschiedener Speicherformen für die Energiewirtschaft), H. Pauer. Wärme, vol. 46, nos. 31, 32 and 33, Aug. 3, 10 and 17, 1923, pp. 341-345, 355-358 and 367-369, 12 figs. Causes of fluctuations between power supply and demand; losses occurring with seasonal short fluctuations; thermal principles of different storage systems; comparison between Ruths and feed-space accumulators.

STEAM-ELECTRIC PLANTS

Barbadoes Island, Pa. Barbadoes Island Plant Illustrates Modern Central Station Design. Power Plant Eng., vol. 27, no. 19, Oct. 1, 1923, pp. 965-973, 12 figs. Electrified auxiliaries, double-effect evaporators, motor-operated valves, starting bus for motors, and loop system of boiler feed are features of design.

Edinburgh, Scotland. Edinburgh's New Power Station. Elec. Ry. & Tramway Jl., vol. 49, no. 1197, Aug. 10, 1923, pp. 73-80, 8 figs. First section of new station at Portobello opened. Administration of development and details of station.

STEAM GENERATORS

Electric. Using Excess Power to Save Coal, E. H. Horstkotte. Indus. & Eng. Chem., vol. 15, no. 9, Sept. 1923, pp. 913-914, 1 fig. Electric generation of steam for heating and process work.

STEAM PIPE

High-Temperature Steam. Piping for High-Temperature Steam (Conduites de vapeur à haute température), Luc Denis. Société d'Encouragement pour l'Industrie Nationale—Bul., vol. 135, no. 5, May 1923, pp. 328-338, 4 figs. Conduction of superheated steam; piping and joints for purpose; arrangement of systems of pipe lines; examples.

STEAM POWER PLANTS

Auxiliaries. Steam Plant Auxiliaries, C. D. Gray and M. M. Samuels. Elec. World, vol. 82, no. 15, Oct. 13, 1923, pp. 749-753, 6 figs. Discusses methods of switching and grouping auxiliaries; arrangements for insuring continuity of service; typical installations; choice of voltage and house-service supply.

Oil-Burning. Power Plant Equipped to Burn Fuel Oil. Ry. Mech. Engr., vol. 97, no. 9, Sept. 1923, pp. 621-622, 3 figs. Flexible boiler operation and labor saving secured by burning oil in enginehouse power plant.

STEAM TRAPS

Installation and Operation. Steam-Trap Installation and Operation, R. N. Robertson. Power, vol. 58, no. 15, Oct. 9, 1923, pp. 573-576, 7 figs. Gives logical reasons for erratic behavior of steam traps and clarifies misunderstandings and rule-of-thumb methods employed.

STEAM TURBINES

Disks, Design of. The Design of Rotating Discs, G. Arrowsmith. Engineering, vol. 116, no. 3014, Oct. 5, 1923, pp. 417-419, 4 figs. In method outlined mathematical accuracy of original solution of Stodola has been maintained, but equations have been so transposed that disks of any reasonable contour can be treated.

Leaving Losses, Reduction of. Devices to Reduce Leaving Losses in Steam Turbines, Ivor R. Cox. Beama, vol. 13, no. 65, Sept. 1923, pp. 175-181, 6 figs. Points out that in order to increase leaving area without increasing blade stress it is necessary to depart from parallel blade and adopt blade the section of which is larger at root than at tip.

Vibration in, Correction of. Correcting Vibration in Reaction Type Turbines, L. Long. Power, vol. 58, no. 16, Oct. 16, 1923, pp. 609-612, 2 figs. Checking a sprung motor; checking trueness of coupling flanges; determining whether vibration is in turbine or generator; other recommendations.

STEEL

Alloy. See ALLOY STEELS.

Chrome-Nickel. See CHROME-NICKEL STEEL.

Elastic Limit. The True and Apparent Elastic Limit of Steel, M. L. Fraichet. Iron & Coal Trades Rev., vol. 107, no. 2896, Aug. 31, 1923, p. 302. Results of tests carried out on wide variety of steels. Translated from Revue de Métallurgie.

Endurance Tests. Endurance Properties of Steel: Their Relation to Other Physical Properties and to Chemical Composition, D. J. McAdam, Jr. Am. Soc. Testing Matls.—advance paper, no. 19, for meeting June 25-29, 1923, 46 pp. 25 figs. Results of endurance tests at U. S. Nav. Eng., Experiment Station on carbon and alloy steels; repeated impact tests were made on machine which is described, as result of which, relationship of repeated impact to single impact and to endurance properties is indicated by graphs.

Fracture. Oblique Fracture and Flake Formation (Schieferbruch und Flockeobildung), Franz Rapatz. Stahl u. Eisen, vol. 43, no. 37, Sept. 13, 1923, pp. 1199-1202, 3 figs. Review of data contained in literature up to end of 1921, from which it is shown that no satisfactory explanation exists as to causes of flakes, and there is diversity of opinions regarding preventive measures.

Noteworthy Fractures (Bemerkenswerte Bruchercheinungen), Richard Baumann. Zeit. des Vereines deutscher Ingenieure, vol. 67, no. 39-40, Sept. 29, 1923, pp. 945-947, 24 figs. It is shown that elongation of structure is observable even after breaking at red heat, when followed quickly by cooling; results of tensile tests on highly heated steel wires; observations on dented water pipes; fractures caused by excessive stress and by rapid change of temperature; influence of rapid increase in pressure in fractures of hollow cylinders.

High-Speed. See STEEL, HIGH-SPEED.

Ingots, Solidification of. Macrographic Study of Solidification of Steel Ingots (Sur l'étude macrographique du refroidissement des lingots d'acier), J. Descolas and E. Pretet. Revue de Métallurgie, vol. 20, no. 9, Sept. 1923, pp. 597-606, 12 figs. Relative importance of peripheral and central zones; effect of velocity of cooling after pouring; propagation of solidification in interior of ingot.

Internal Strains. Internal Strains in Cold Worked, Cold Pressed or Cold Bent Carbon Steel, W. J. Merten. West. Machy. World, Sept. 1923, vol. 14, no. 9, pp. 285-286 and 289, 7 figs. Points out that timely and judicious application of annealing for relieving of internal strains, accompanied by proper design of drawing dies and proper clearance, are all important to cold, deep drawing practice.

Specifications. Report of Committee A-1 on Steel. Am. Soc. for Testing Matls.—advance paper, no. 7, for meeting June 25-29, 1923, 39 pp., 29 figs. Recommendations affecting standards and tentative standards; recommendations for steel rails and accessories, structural steel, steel castings, steel tubing and pipe, boiler steel; methods of chemical analysis and physical tests; commercial bar steels, plate tolerances, steel for welding. Proposed revisions in standards. Report on ladle test ingot investigation; proposed specifications for steel castings and steel plate.

Sulphur in. Summarizes Work on Sulphur in Steel. Iron Trade Rev., vol. 73, no. 15, Oct. 11, 1923, pp. 1023-1024. Abstract of committee report outlining progress made and summarizing investigations planned by joint committee.

Temperature, Effect on Properties. The Effect of Temperature on Some of the Properties of Steel, H. R. A. Mallock. Roy. Soc.—Proc., vol. 103, no. A720, Apr. 3, 1923, pp. 1-7, 9 figs. Results of experiments now in progress at Davy-Faraday laboratory, on effect of temperature on elastic coefficient of solids.

Tensile Strength. Effect of Temperature on the Tensile Strength of Steel. Ry. & Locomotive Eng., vol. 36, no. 10, Oct. 1923, pp. 307-308, 1 fig. Presents table showing results of series of investigations on ten steels of different carbon and manganese content.

Tests, Magnetic. Magnetic Testing of Steel (Essai magnétique des aciers à la traction. Limites élastiques), L. Fraichet. Revue de Métallurgie, vol. 20, no. 8, Aug. 1923, pp. 549-559, 13 figs. Results of tests made; apparatus used; elastic limits; etc.

STEEL CASTINGS

Heat Treatment. Steel Castings Viewed Through the Microscope, M. G. Dumas. Ry. Rev., vol. 73, no. 13, Sept. 29, 1923, pp. 456-462, 17 figs. Fundamentals underlying scientific heat treatment of plain carbon steel castings.

Modern Trend. Outline Steel Casting Trend, Edgar A. Custer. Foundry, vol. 51, no. 19, Oct. 1, 1923, pp. 789-791. Green sand molds, rammed hard, becoming more widely used; rigid and accurately machined flasks and equipment aid; field pointed out for making castings in dry sand cores.

STEEL, HEAT TREATMENT OF

Automobile Steels. Automobile Steels and their Heat Treatment, P. A. Shaw. Eng., Production, vol. 6, no. 133, Oct. 1923, pp. 418-420, 2 figs. Effects of different elements in steel when treated; operations of normalizing, annealing, carburizing, hardening, and tempering.

Hardening. The Hardening of Steel, Zay Jeffries and R. S. Archer. Am. Soc. for Steel Treating—Trans., vol. 4, no. 3, Sept. 1923, pp. 263-304, 7 figs. Gives general definition of hardness, general theory of hardening of metals, and detailed conception of nature of hardened steel and of causes for its hardness.

Ingot Structure. Ingot Structure and Heat Treatments, B. D. Sakalatwalla. Iron Age, vol. 112, no. 13, Sept. 27, 1923, pp. 815-816. Importance of controlling former as aid to latter; possible effect of electromagnetic treatment during solidification.

Long-Time Drawing, Effect of. Heat-Treated Steel Parts in Service, George K. Elliott. Iron Age, vol. 112, no. 31, Sept. 27, 1923, pp. 810-811. Effect of long-time drawing conditions or further heat treatment under use; stability of steel.

Magnetic Inspection. A New Method of Magnetic Inspection, A. V. de Forest. Am. Soc. Testing Matls.—advance paper, no. 22, for meeting June 25-29, 1923. 12 pp., 6 figs. Rapid method of nondestructive test and inspection has been developed; by suitable combination of two independent magnetic readings, it is possible to determine different effects of two different factors entering into treatment of steel; method has been applied to study of different magnetic effects of quenching and drawing processes on 1-per cent tool steel and 18-per cent tungsten high-speed steel.

Quenching, Effect of. The Effect of Quenching from above the Carbide Transition Temperature upon the Magnetism of Steel, A. A. Dee. Roy. Soc.—Proc., vol. 104, no. A725, Sept. 1, 1923, pp. 316-321, 4 figs. Results of experiments indicate that quenching does not suppress transformation.

Variations in Volume Undergone by Hollow Steel Objects when Quenched (Variations de capacité accompagnant les traitements thermiques des corps creux en acier), Albert Portevin. Comptes Rendus, des Séances de l'Académie des Sciences, vol. 176, no. 13, Mar. 26, 1923, pp. 897-902. Changes in volume of cavity in 75-mm. steel shell caused by

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quenching is given in table, which shows that method of quenching is of great importance; repetition of treatment causes continued growth, which appears to be due to tendency to assume spherical form.

Tool Steel. Activity of Sub-Committee—1, on Recommended Practice for Treatment of Tool Steel during 1922–23. Am. Soc. for Steel Treating, vol. 4, no. 3, Sept. 1923, pp. 397–406. Recommended practice in heat treatment of plain carbon tool steel and in heat treatment of 18-per cent tungsten high-speed steel.

STEEL, HIGH-SPEED

Effect of Heat Treatment on Properties. The Effect of Heat Treatment on Lathe Tool-Performance and Some Other Properties of High-Speed Steels, H. J. French, Jerome Strauss and T. G. Diggs. Am. Soc. for Steel Treating, vol. 4, no. 3, Sept. 1923, pp. 353–396, 10 figs. Deals with time-temperature relation in hardening and tempering of high-speed steels and their effects upon lathe-tool performance, constitution and dimensional changes. Comparisons of "Taylor" and "breakdown" tests for lathe tools; consideration of prevention and elimination of so-called "flaky fractures" in heat treatment of high-speed steels.

Hardening. Hardening High Speed Steel, W. B. Sullivan. Forging—Stamping—Heat Treating, vol. 9, no. 9, Sept. 1923, p. 375. Method developed by Chrobaltic Tool Co., Chicago, consists of heating tool in protected atmosphere to predetermined time and temperature, cooling in most appropriate manner and drawing at predetermined time and temperature.

Hardness after Quenching. Secondary Hardness of High-Speed Steel Heated After Quenching (Sur la "dureté secondaire" de l'acier rapide chauffé après la Trempe), G. Z. Nesselstraus. Revue de Métallurgie, vol. 20, no. 4, Apr. 1923, pp. 174–180, 13 figs. Series of chromium steels containing tungsten or cobalt, tungsten steel, and two carbon steels were studied by means of thermal analysis, hardness measurement, and microscopic examination; results.

STEEL MANUFACTURE

Converters. Practical Problems in the Operation of Large and Small Bessemer Converters (Praktische Betriebsfragen aus der Gross- und Kleinbessemerei), Huber Hermanns. Giesserei-Zeitung, vol. 20, nos. 16 and 17, July 15 and Aug. 1, 1923, pp. 297–300 and 325–327, 9 figs. Electric drive of converters; problems of transport; conveyance of pig iron and steel; foundry equipment.

STEEL WORKS

D. C. Power Generation. Direct-current Power Generation for Steel Plant Loads, Ernest Pragst. Gen. Elec. Rev., vol. 26, no. 10, Oct. 1923, pp. 672–677, 6 figs. Analyzes pros and cons of various methods of obtaining adequate amount of a.c. power for operating auxiliary drives, and makes recommendations to suit different needs.

STREET RAILWAYS

Cars, Worm-Drive. New Worm Drive Tramcar, Aera, vol. 12, no. 2, Sept. 1923, pp. 175–179, 2 figs. Hull Corporation Tramways has built a double-deck car incorporating automobile type of drive, with split axles, suspended motors, and other novel features.

SUPERHEATERS

Multi-Flow. Multi-Flow Steam Superheaters. Engineer, vol. 136, no. 3536, Oct. 5, 1923, pp. 376–377, 6 figs. Improved form of double-flow superheater, specially designed for use in downtake at rear of Lancashire and Galloway boilers.

SURGE TANKS

Mathematical Analysis. An Analysis of the Surge Tank of Constant Area and Unlimited Height, H. W. Coultas. Beama, vol. 13, no. 66, Oct. 1923, pp. 233–240, 5 figs. Mathematical analysis based on curves showing flow in tunnel, friction head, acceleration head and level in surge tank against time.

T

TEMPERATURE CONTROL

Apparatus. Temperature Control Apparatus (Note sur un contrôleur de température), Alfred Guy. Société d'Encouragement pour l'Industrie Nationale—Bul., vol. 135, no. 5, May 1923, pp. 341–345, 3 figs. New patent device in which heat is automatically cut off on reaching a different temperature; gives various examples of application, such as electric irons gas heaters, metal furnaces.

TEMPERATURE MEASUREMENT

Heated Walls. The Course of Temperature in Heated Walls of any Given Form (Temperaturverlauf in geheizten Wandungen von heliebiger Form), J. Geiger. Zeit. des Vereines deutscher Ingenieure, vol. 67, no. 37, Sept. 18, 1923, pp. 905–908, 11 figs. Describes simple and practical method of determining temperature in heated walls of any form, thickness or shape.

TERMINALS, RAILWAY

Design. Design of Railway Terminal Stations, Alfred Fellheimer. Contract Rec., vol. 37, no. 35, Aug. 29, 1923, pp. 844–846. Essential consideration concerned in efficient station layout; anticipation of electrification; coördination of long- and short-haul traffic.

TESTING MACHINES

Hardness. Testing of Steel for Hardness, H. M. German. Am. Soc. for Steel Treating—Trans., vol. 4, no. 3, Sept. 1923, pp. 329–341, 5 figs. Deals with most important factors and elements that introduce errors in operation of Brinell, and Rockwell machines and scleroscope.

TESTS AND TESTING

Methods. Report of Committee E-1 on Methods of Testing. Am. Soc. for Testing Matls.—advance paper, no. 4, for meeting June 25–29, 1923, 36 pp., 14 figs. Classification of testing methods; tentative methods; revision of standard methods of mechanical testing of metallic materials; suggested methods of tension testing of metallic materials; proposed tentative definitions of terms relating to methods of testing; and for verification of testing machines.

TEXTILE MACHINERY

Speed Control. Mechanical and Electrical Speed Control, C. T. Guildford. Textile World, vol. 64, no. 9, Sept. 1, 1923, pp. 79–82, 6 figs. Combination for tandem drives on cloth-finishing machines; alternating current motors and control, with automatic electrically operated mechanical variable speed transmission at plant of Rockland Bleach & Dye Works Co., Brooklandville, Md. Saving in labor and increased production.

THERMOMETERS

Remote-Reading. Distance Thermometers for Temperatures Below 700 Degrees (Rationella distanstermometrar för temperaturer under 700°), C. H. Marell. Teknisk Tidskrift, vol. 53, no. 10, Mar. 10, 1923, pp. (Allmänna Avdelningen) 73–74, 5 figs. Describes expansion thermometers (solid, liquid and gas), also thermoelectric, and resistance types.

Specifications. Report of Committee D-15 on Thermometers. Am. Soc. Testing Matls., advance paper, no. 71, for meeting June 25–29, 1923, 12 pp. Proposed specifications for A.S.T.M. partial immersion thermometers and for A.S.T.M. thermometers for use with Saybolt viscosimeter.

TIRES, RUBBER

Cord. Weftless Cord Tire Construction. India Rubber World, vol. 68, no. 6, Sept. 1, 1923, pp. 759–761, 2 figs. New weftless textile product yielding more fabric yardage per lb. of cotton, more homogeneous, resilient and wear-resisting carcass at less cost.

Fire Apparatus. Some Experiences with Fire Apparatus Tires, W. Russell. Fire & Water Eng., vol. 74, no. 10, Sept. 5, 1923, pp. 445–446. Climatic conditions and kind of apparatus in use govern type of tire most suitable; average life of tires depends on conditions.

Low-Pressure. Low Pressure Tyres. Auto-Motor Jl., vol. 28, no. 38, Sept. 20, 1923, p. 797, 4 figs. Particulars of new Dunlop big air tires.

TOOL MAKING

Master-Plate Method. The Master Plate in Press Tool Making, W. Richards. Machy. (Lond.), vol. 22, no. 571, Sept. 6, 1923, pp. 717–720, 11 figs. Examples of master plates and their application.

TRACTORS

Peat-Soil-Breaking. Tractor and Plow Usage in the First Breaking of Peat Land, J. Lyman Larson. Soc. Automotive Engrs.—Jl., vol. 13, no. 4, Oct. 1923, pp. 285–292 and (discussion) 292–295, 28 figs. Tract comprising several acres of "tamarack" swamp, drained with tile and cleared of stumpage was utilized to obtain accurate information regarding tractor and plowing equipment required for heavy operations of first breaking of peat soil, 5 to 7 ft. deep; equipment used and procedure.

"Super-Sentinel." The "Super-Sentinel" Tractor. Motor Transport (Lond.), vol. 37, no. 967, Sept. 10, 1923, pp. 333–334, 4 figs. Details of design of steam tractor designed for standardized production; direct drive.

TRAILERS

Trailmobile Universal Chassis. Trailmobile Universal Chassis, Caleb W. Shipley. Army Ordnance, vol. 3, no. 19, July-Aug. 1923, pp. 23–28, 7 figs. Cost of trailmobile universal chassis more than offset by economies it effects in replacement parts and flexibility of service alone; other economies; details of design.

TRANSPORTATION

Highway. Road Transport, A. E. Berriman. Engineering, vol. 116, no. 3012, Sept. 21, 1923, pp. 380–381. Deals with freight transport by road and by rail; types of commercial vehicles and their suitability for different purposes; passenger vehicles; road improvement and traffic control. Paper read before Brit. Assn.

Railway. The Future of Transportation by Rail, E. O'Brien. Engineering, vol. 116, no. 3012, Sept. 21, 1923, pp. 381–382, 1 fig. Survey of probabilities of future of rail transport with brief reference to past. Paper read before Brit. Assn.

Science, Indebtedness to. Transport and Its Indebtedness to Science, Henry Fowler. Engineering, vol. 116, no. 3012, Sept. 21, 1923, pp. 377–380, 1 fig. Discusses investigations which led to development and perfection of steam and internal-combustion engines; scientific work in aeronautics; advances in metallurgy. Address before Brit. Assn.

TUBES

Steel, Manufacture of. Newport Works of The British Mannesmann Tube Company, Limited. Iron & Coal Trades Rev., vol. 107, no. 2897, Sept. 7, 1923, pp. 327–328, 6 figs. partly on p. 329. Latest addition is new plant for manufacture of lap-welded steel tubes, capable of manufacturing tubes from 14 in. up to 72 in. in diam. in lengths up to 25 ft.

V

VALVES

Pressure-Reducing. An Original Type of Reducing Valve. Power Engr., vol. 18, no. 211, Oct. 1923, pp. 385–386, 2 figs. Describes principle and characteristics of Clark's reducing valve, made under Eyre's patent.

Pump. Ismailia Valves for Pumps and Mains. Engineering, vol. 116, no. 3013, Sept. 28, 1923, pp. 392–393, 13 figs. Valve in which ordinary hinge arrangement has been eliminated from design was introduced for use at Ismailia pumping station at Cairo; application is being extended to general field of service where liquids contain sand, grit, refuse and other solid matter.

VARNISHES

Tests. Report of Sub-Committee IX on Varnish. Am. Soc. for Testing Matls., advance paper, no. 48s, for meeting June 25–29, 1923, 17 pp., 6 figs. The "Kauri" reduction test as accelerated method of determining durability of varnish; exposure test, and results; proposed methods of testing oleoresinous varnishes.

VENTILATION

Office Buildings. The Ventilation of Office Buildings, Charles L. Hubbard. Bldg. Age., vol. 45, no. 9, Sept. 1923, pp. 66–68, 6 figs. Suggestions for improving ventilating conditions in buildings already in process of preparation or in use.

VISCOSIMETERS

Combined Plastometer and. A New Combined Viscometer and Plastometer, E. C. Bingham and H. A. Murray, Jr. Am. Soc. Testing Matls., advance paper, no. 76, for meeting June 25–29, 1923, 9 pp., 2 figs. Proposes new principle in viscometry where shearing stress is varied by allowing material to enter capillary under constant pressure head; advantages of method.

W

WAGES

Minimum-Wage Law. Some Effects of the Operation of the California Minimum Wage Law, Louis Bloch. Monthly Labor Rev., vol. 17, no. 2, Aug. 1923, pp. 1–12. Summarizes results of operation of law, revealed by statistics gathered by California Industrial Welfare Commission.

Piecework System. Piece Work Wage Payment in the Soap Industry, N. Shapiro. Indus. Management (N. Y.), vol. 66, no. 4, Oct. 1923, pp. 228–229. System that promotes good work and good will.

WATER POWER

Optimum Power of Heads. Determining the Optimum Power of which Heads of Water are Capable (Sur la détermination de la puissance optimum d'aménagement des chutes d'eau), E. Baticle. Houille Blanche, vol. 22, no. 183, July-Aug. 1923, pp. 132–134, 4 figs. Variability of quantity of water available; curves of actual water supply; their use in determining optimum; examples and calculations.

Tennessee. A Study of Some of the Smaller Undeveloped Water Powers of Tennessee, J. A. Switzer. State of Tenn. Dept. Education, Division of Geol., Bul. 30, 1923, 24 pp., 37 figs. on supp. plates. Red River, Chestuee Creek, Cummins Falls, Harpeth River, Buffalo River, and Nolichucky River projects; "Narrows" of Caney Fork; Obed River, Piney River and Soddy Creek investigations.

WELDING

Electric. See ELECTRIC WELDING; ELECTRIC WELDING, ARC.

Oxy-Acetylene. See OXY-ACETYLENE WELDING.

Speed In. Speed Versus Good Welding, R. G. Mason. Am. Welding Soc.—Jl., vol. 2, no. 8, Aug. 1923, pp. 10–12, 1 fig. Troubles resulting from speedy welding.

WIRE ROPE

Stresses. Stresses in Wire Rope (Beitrag zur Kenntnis der Vorspannungen in Drahtseilen), A. Werner. Glückauf, vol. 59, nos. 31 and 32, Aug. 4 and 11, 1923, pp. 741–745 and 772–777, 7 figs. Aug. 4: Theory of wire rope and present method of manufacture, especially recommending changes in form and tension; deformation of wire in lacing machine Aug. 11: Deformation in strands on making into rope, explained by mathematical calculations.

Z

ZINC ALLOYS

Machine-Tool Bearings, for. Copper-Poor Zinc Alloys for Machine-Tool Bearings, the Influence of Casting and Lubrication (Kupferarme Zinklegierungen für die Lagerungen der Werkzeugmaschinen, Einfluss des Gieszens und der Schmierung), G. Schlesinger and M. Kurrein. Werkstattstechnik, vol. 17, nos. 16 and 17, Aug. 15 and Sept. 1, 1923, pp. 481–487 and 522–526, 24 figs. Account and results of tests for purpose of substituting for bronze bearings, bearings of zinc alloys with little or no copper content. Report of experimental department for machine tools of Charlottenburg Technical Academy.

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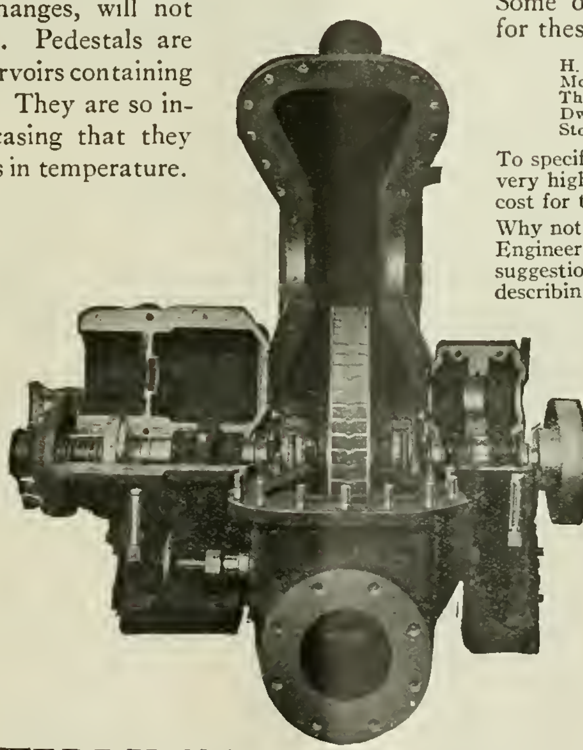

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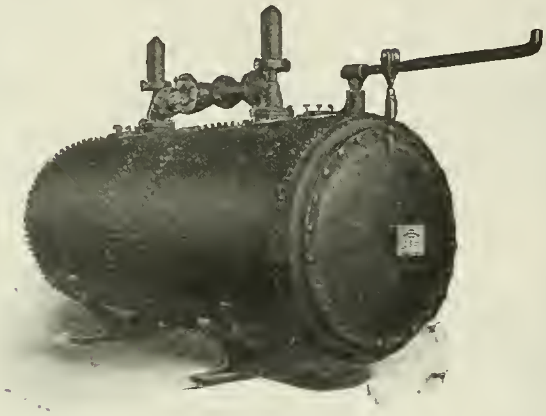

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